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IS 7305 (1984): Fixed Capacitors Used in Electronic Equipment [LITD 5: Semiconductor and Other Electronic Components and Devices]

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Bhartṛhari—Nītiśatakam

“Knowledge is such a treasure which cannot be stolen”



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IS : 7305 - 1984

Indian Standard
SPECIFICATION FOR
FIXED CAPACITORS USED IN
ELECTRONIC EQUIPMENT
(First Revision)

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 1985

Indian Standard
**SPECIFICATION FOR
 FIXED CAPACITORS USED IN
 ELECTRONIC EQUIPMENT**
(First Revision)

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Indian Standard
**SPECIFICATION FOR
FIXED CAPACITORS USED IN
ELECTRONIC EQUIPMENT**
(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 12 June 1984, after the draft finalized by the Capacitors Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to lay down the general requirements and uniform test procedures applicable to large families of capacitors so that unnecessary variations in the individual standards covering different types of capacitors are avoided. It is realized that such a step will enable uniform description of the characteristics of the capacitors by the manufacturers as well as user.

0.3 In this standard, procedures for testing the characteristics of different families of capacitors, have been given. Not all these test procedures will be applicable to all the capacitors. In the individual capacitor specification reference to the applicable tests will be made in addition to specifying specific values for the different characteristics and any additional requirements and tests pertinent to that type of capacitors.

0.4 This standard was originally published as IS : 7305 (Part 1) - 1973 and was largely based on IEC Publication 384-1 (1972) Fixed Capacitors for use in Electronic Equipment : Part 1 Terminology and methods of tests, issued by the International Electrotechnical Commission (IEC). The standard is now being revised to bring it in line with the latest edition of the IEC Publication.

0.4.1 It was earlier envisaged to prepare this standard as a series with Part 1 covering General requirements for all types of fixed capacitors and subsequent parts covering general requirements of different types of capacitors. However, it has now been decided to bring out general requirements and methods of tests for different families of capacitors depending on type of dielectric used, under different IS numbers. As such this standard is being designated as IS : 7305 and Part II of this standard has also been re-designated as IS : 10825 (Part I) - 1975.

0.5 Appendix A of this standard gives endurance test to cover capacitors under pulse conditions.

0.6 While preparing this standard assistance has been derived from the following :

IEC Pub 384-1 (1982) — Fixed capacitors for use in electronic equipment. Part 1 Generic specification. The International Electrotechnical Commission (IEC).

JSS 50 200 General requirements for capacitors, fixed. Directorate of Standardization, Department of Defence Production, Ministry of Defence, New Delhi.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the general requirements and tests applicable to different types of fixed capacitors, having reactive power rating less than 200 VA_r, intended for use in electronic and other similar equipment.

2. TERMINOLOGY

2.1 For the purpose of this standard following terms and definitions in addition to those given in IS : 1885 (Part 45)-1977† shall apply.

2.2 Terms Related to Pulse Testing of Capacitors

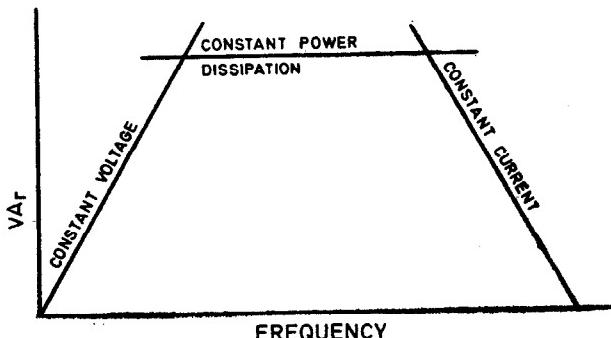
2.2.1 Rated ac Load — The rated load (ac) is the maximum ac which may be applied continuously to the terminals of a capacitor at any temperature between the lower category temperature and the rated temperature. It may be expressed as :

- a) at low frequencies a rated voltage (U'_R),
- b) at high frequencies a rated current (I'_R), and
- c) at intermediate frequencies a rated VA_r or power dissipation (P'_R).

*Rules for rounding off numerical values (revised).

†Electrotechnical vocabulary : Part 45 Capacitors.

This is shown diagrammatically in the figure :



Note 1 — For a particular type of capacitor it may be necessary to specify one or more of the above.

Note 2 — Capacitors within the scope of this specification are normally less than 500 VA, at 50 Hz. Low frequencies may be 50, 100 or 400 Hz. Voltages may be up to 600 V at 50 Hz. However, capacitors for filters, transmitter or converter circuits may be required to operate under power over a wide range of frequencies and at up to 10 kVAr at the higher frequencies. Voltages may be up to 1 000 Vrms.

2.2.2 Pulse Rated Load — The pulse rated load is the maximum load which may be applied at a certain pulse repetition frequency to the terminals of a capacitor at any temperature between the lower category temperature and the rated temperature. It may be expressed by (a), (b) and any of the remaining items :

- a) peak current per μF or $\frac{dv}{dt} \text{ V}/\mu\text{s}$;
- b) relative duration of charge and discharge periods;
- c) rms current (I''_R);
- d) peak voltage (U''_R);
- e) peak reverse voltage;
- f) pulse repetition frequency (prf) (see Note); and
- g) maximum permitted power dissipation (P''_R) or temperature rise (where applicable).

NOTE — In the case of intermittent pulses the duty cycle shall be specified. In the case of random pulses the total number expected over a given time period shall be stated.

2.2.3 Pulse rms Current — This pertains to the square root of the average of the squares of the values of the magnitude. If the magnitude takes in-discrete values (m_j) its rms value is :

$$V_{\text{rms}} = \left[\left(\frac{1}{n} \right) \sum_{j=1}^n m_j^2 \right]^{\frac{1}{2}}$$

If the magnitude is a continuous function of time $m(t)$ its rms value is

$$V_{\text{rms}} = \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} m^2(t) dt \right]^{\frac{1}{2}}$$

The summation or the integral extends over the internal of time for which the rms value is desired or, if the function is periodic, over any integral number or periodic repetition of the function. In the case of intermittent or random pulses the time interval shall be chosen to correspond with the maximum temperature rise.

2.2.4 Pulse Equivalent Circuit of a Capacitor — For practical purposes the pulse equivalent of a capacitor is resistance in series with capacitance together with its residual inductance.

Note — The equivalent series resistance shall be similar to but not identical with the ESR measurement under sine wave (analog) conditions. The pulse ESR shall take into account the series of harmonics in the pulse and the variation of the losses at these frequencies.

2.2.5 Temperature Rise — The rise of temperature of the capacitor relative to the external ambient resulting from the losses in it due to operation under ac or pulse conditions.

2.3 Minimum Storage Temperature — The minimum permissible ambient temperature which the capacitor shall withstand in the non-operating condition without damage.

Note — The maximum permissible storage temperature is equal to the upper category temperature.

2.4 Visible Damage — Damage which reduces the usability of the capacitor for its intended purpose.

2.5 Type — A group of capacitors having similar design features and the similarity of whose manufacturing techniques enables them to be grouped together either for type test or for acceptance tests.

Note — Capacitors described in several detail specifications, may, in some cases, be considered as belonging to the same type and may therefore be grouped together for type and acceptance tests.

2.6 Style — A sub-division of a type, generally based on dimensional factors. A style may include several variants, generally of a mechanical order.

2.7 Grade — A term to indicate additional general characteristics concerning the intended application for example, long life applications. The term 'Grade' may only be used in combination with one or more words (for example long life grade) and not by a single letter or number. Figures to be added after the term 'Grade' should be numerals.

2.8 Type Tests — Tests carried out to prove conformity with the requirements of the standard. These are intended to prove the general quality and design of a given type of capacitor.

2.9 Acceptance Tests — Tests carried out on samples selected from a lot for the purpose of acceptance of the lot.

2.9.1 Lot — All capacitors of the same category and rating, manufactured by the same factory and during the same period.

2.10 Routine Tests — Tests carried out on each capacitor to check the requirements which are likely to vary during production.

3. DESCRIPTION AND CODE

3.1 The description of the type of the capacitor may be in the form of a four character code, consisting of alphabets $\frac{xx}{1} \frac{xx}{2}$ as follows :

Group 1 — FC — Fixed capacitors

Group 2 — AL — Aluminium electrolytic

CG — Ceramic, general purpose

CM — Polycarbonate, metallized

CT — Ceramic, temperature compensating

FT — Foil, tantalum

MA — Mica

PC — Polycarbonate

PE — Polyester

PP — Polypropylene

PS — Polystyrene

PM — Polyester, metallized

ST — Solid tantalum

Further each type may have different styles indicated by 1, 2, 3, etc. after the above four digits.

4. CLIMATIC CATEGORIES

4.1 The climatic categories shall be as specified in the relevant specification.

5. RATINGS

5.1 Rated Capacitance — The values of the rated capacitance shall be suitably chosen from IS : 824-1965*.

5.2 Tolerance on Rated Capacitance — The tolerance on the rated capacitance shall be stated in the relevant specification.

*Preferred values for resistors and capacitors (*revised*),

5.3 Rated Voltage — Unless otherwise specified in the relevant specification, the values of rated voltages shall be chosen from basic R 5 series with intermediate values, if necessary, chosen from R 10 series given in IS : 1076-1967*.

Note — Any qualification such as superimposed ac, its limiting value, etc should be specified in the relevant specification.

5.4 Rated Temperature — The maximum ambient temperature at which the rated voltage may be continuously applied.

6. CONSTRUCTION AND WORKMANSHIP

6.1 Construction

6.1.1 *Terminals*

6.1.1.1 Unless otherwise specified, the terminals shall either be in the shape of tags or wires, and so coated as to be easily solderable.

6.1.1.2 The capacitors shall have the wire terminals of length stated in the relevant specification.

6.1.1.3 The preferred nominal diameters of basic wires (untinned) used for terminations shall be in accordance with the following:

0·30, 0·40, 0·50, 0·60, 0·70, 0·80, 0·90, 1·00, and 1·20 mm.

6.1.1.4 Each strip¹ termination shall have a minimum cross-sectional area of 0·40 mm² with a maximum width of 1·1 mm.

6.2 Finish — Unless otherwise specified, all exposed materials liable to deterioration in moist or other corrosive atmosphere shall be given suitable finish.

6.3 Workmanship — All parts shall be manufactured in a thoroughly workmanlike manner and in accordance with good engineering practice.

7. MARKING

7.1 The items to be marked on the capacitor shall be stated in the relevant specification.

Note — If coded marking of values and their tolerances by means of letters and digits are used, it shall be in accordance with IS : 8186-1977†.

7.2 The marking shall be such as not to become illegible while in storage and during service through reasonable handling.

*Preferred numbers (*first revision*).

†Marking codes for values and tolerances of resistors and capacitors.

7.3 The capacitors may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

8. TESTS

8.1 Classification of Tests

8.1.1 Type Tests — The type tests shall be as stated in the relevant specification. The procedure for the approval of the type shall be in accordance with IS : 2612-1965*.

8.1.1.1 Number of samples — The number of samples shall be given in the relevant specification.

8.1.2 Acceptance Tests — The acceptance tests shall be carried out on a limited number of samples selected in accordance with the sampling plan given in IS : 2612-1965* and which have passed the routine tests. The acceptance tests shall be stated in the relevant specification.

8.1.3 Routine Tests — The routine tests that should be carried out on all components shall be as specified in the relevant specification.

8.2 General Conditions for Tests

8.2.1 Atmospheric Conditions for Tests — Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as specified in IS : 9000 (Part 1)-1977†.

8.2.2 Preconditioning — Before measurements are made, the capacitors shall be stored at the measuring temperature and relative humidity for sufficient time to allow the entire capacitor to reach these conditions. The recovery period prescribed after climatic conditioning is adequate for this purpose.

8.2.3 Corrections to be Applied — When measurements are made at temperature other than the specified temperature, the result shall, where

*Recommendation for type approval and sampling procedures for electronic components.

†Basic environmental testing procedures for electronic and electrical items: Part 1 General.

necessary, be corrected to the specified temperature. The ambient temperature during the tests shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using a standard reference temperature and such other conditions as are prescribed in this specification.

Where tests are conducted in a sequence the final measurements of one test may be taken as the initial measurements for the succeeding test.

8.2.4 Recovery Conditions — Unless otherwise specified recovery shall take place under the standard atmospheric conditions for testing. If recovery has to be made under closely controlled conditions, the standard recovery conditions of 3.4.3 of IS : 9000 (Part 1)-1977*, shall be used.

Unless otherwise specified in the relevant specification a duration of 1 to 2 hours shall be used.

8.2.5 Drying — Where drying is called for in this standard and unless otherwise specified in the relevant specification, the capacitor shall be conditioned, before measurement is made, for 96 ± 4 hours in a dry oven at a temperature of $55 \pm 2^\circ\text{C}$ and a relative humidity not exceeding 20 percent. The capacitor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

NOTE 1 — In cases where dry heat severity is lower than 55°C , the drying shall be carried out at that lower temperature.

NOTE 2 — Storage at 55°C may cause a change in the properties of the dielectric with consequent change in the capacitance readings.

8.2.6 Method of Test or Measurement — The method used initially for any test or measurement and the equipment used shall, unless otherwise specified, be used for all subsequent applications of that test or measurement. In addition, for all capacitance measurements, the disposition of the capacitors under test and their connecting leads shall be, as far as possible, identical.

8.2.7 Precautions — During measurement, the capacitors shall not be exposed to draughts, direct sun rays or other influences likely to cause error. The capacitors shall be discharged through a proper discharge resistor.

8.3 Electrical Tests

8.3.1 Voltage Proof — The test, prescribed below, is a dc test. When the relevant specification prescribes an ac voltage proof test, the same test procedure shall be used except that an alternating voltage shall be applied in place of a direct voltage.

*Basic environmental testing procedures for electronic and electrical items : Part 1 General.

8.3.1.1 An example of a suitable test circuit is given in Fig. 1.

Note — The capacitor C_1 may be omitted for certain types of capacitors. This should be stated in the relevant specification.

8.3.1.2 The resistance of the voltmeter shall be not less than $10 \text{ k}\Omega/\text{V}$.

8.3.1.3 The resistances R_1 and R_2 shall be chosen so that in conjunction with the capacitance C_1 and the capacitance of the capacitor under test, the charging and discharging currents do not exceed the specified value at the highest voltage. The capacitance of C_1 shall be at least 10 times the capacitance of the capacitor under test.

8.3.1.4 The switch shall be connected to R_2 . The two terminals a and b shall be connected to a variable dc supply to sufficient power which shall be adjusted to the required test voltage. The capacitor to be tested C_x shall be connected as shown.

The switch shall then be connected to R_1 so that the capacitors C_1 and C_x are charged.

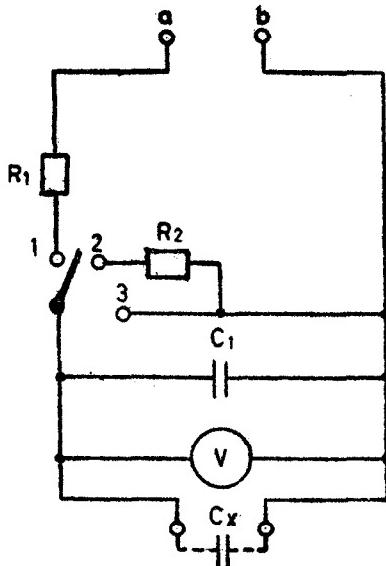


FIG. 1 SUITABLE CIRCUIT FOR THE VOLTAGE PROOF TEST

The switch shall remain in this position for the time specified after the test voltage has been reached. The capacitor shall be discharged by connecting the switch to R_2 . As soon as the voltmeter reading has fallen to zero the capacitors shall be short-circuited and C_x shall be disconnected.

8.3.1.5 The test shall be made at successive points of application as specified in Table 1.

TABLE 1 TEST POINTS

(Clauses 8.3.1.5, 8.3.1.9, 8.3.6.3 and 8.3.6.6)

TEST (1)	MAIN TEST POINT (2)	SINGLE SECTION CAPACITORS (3)	MULTIPLE SECTION CAPACITORS HAVING A COMMON TERMINATION FOR ALL SECTION (4)	MULTIPLE SECTION CAPACITORS HAVING NO COMMON TERMINATION (5)
Between termination	A—Between terminations	Between terminations	Between each of the terminations and the common termination	Between terminations of each section
Internal insulation	B—terminal to case or section to section	Between terminations connected together and the case (except where the case is one termination) (metal cased types only)	Between all terminations connected together and the case (except where the case is one of the terminations) (metal cased types only)	Between all terminations connected together and the case (metal cased types only)
			Between the non-common termination of each section and all the other terminations connected together	Between the terminations of separate sections, the two terminations of each section being connected together
External insulation	C—i) Insulated case to terminations	Between terminations connected together and the metal plate or foil (insulated types not employing metal cases)	Between all terminations connected together and the metal plate or foil (insulated types not employing metal cases)	Between all terminations connected together and the metal plate or foil (insulated types not employing metal cases)
External insulation	C—ii) Insulated metal case to metal plate or foil	Between case and the metal plate or foil (insulated metal cased types only)	Between case and the metal plate or foil (insulated metal cased types only)	Between case and the metal plate or foil (insulated metal cased types only)

8.3.1.6 For test points *B* and *C* (*see* Table 1) when the case of the capacitor is non-metallic or when the capacitor has a metallic case with an insulating sleeve, the test voltage shall be applied in one of the three following ways:

- a) A metal foil shall be closely wrapped around the body of the capacitor to within a distance from the terminations equal to approximately 1 mm/kV test voltage with a minimum 0.5 mm. The test voltage shall be applied between the terminations connected together and this foil.
- b) The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 12.5 mm beyond the mounting face of the capacitor in all directions; the test voltage shall be applied between the terminations connected together and this foil.
- c) The capacitor shall be clamped in the through of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block. The clamping force shall be such as to maintain adequate contact between the capacitor and the block. The terminations shall be so positioned that the distance between the terminations and any point of the V-block is not less than:
 - i) for cylindrical capacitors: the radius of the capacitor body minus the radius of the circumscribed circle of the terminations (the larger circle when the two terminations have different dimensions); and
 - ii) for rectangular capacitors : half the smaller side of the capacitor body minus the radius of the circumscribed circle of the terminations (the larger circle when the two terminations have different dimensions).

Any out-of-centre positioning of the termination at its emergence from the capacitor body shall be ignored.

8.3.1.7 Rate of voltage applied — The voltage shall be steadily increased from zero to the proof value at a rate of approximately 500 V/(rms or dc)/s, unless otherwise specified. The proof voltage shall be maintained for a period of 1 minute \pm 5 seconds, unless otherwise specified. Where dc proof voltage is specified the ripple content shall not exceed 5 percent rms of the proof value. When required, a suitable current limiting device shall be used to limit current surges to the value specified. Upon completion of the test, the proof voltage shall be gradually reduced to avoid voltage surges.

8.3.1.8 Repeated application of the voltage proof test may cause permanent damage to the capacitor and should be avoided as far as possible.

8.3.1.9 The relevant specification shall prescribe:

- a) the test voltage and test points (*see* Table 1) ;

- b) the method of applying the test voltage (either a, or b or c of 8.3.1.6) ;
- c) the duration of the test ;
- d) the maximum charging and discharging current ; and
- e) when applicable, the maximum value of time constant $R_1 (C_1 + C_x)$.

8.3.1.10 There shall be no sign of breakdown or flashover during the test period.

8.3.2 Capacitance

8.3.2.1 The capacitance shall be measured at one of the following frequencies unless otherwise prescribed by the relevant specification:

Electrolytic capacitors:	100 Hz	
Metallized film		
dielectric capacitors	$\leq 1 \mu\text{F}$	1 kHz
	$> 1 \mu\text{F}$	50 Hz
Plastic film dielectric capacitors	$\leq 1 \mu\text{F}$	1 kHz
	$> 1 \mu\text{F}$	100 Hz
Other capacitors	$\leq 1 \text{nF}$	100 kHz or 1 MHz (1 MHz shall be reference)
	$> 1 \text{nF}$ but $\leq 10 \mu\text{F}$	1 kHz or 10 kHz (1 kHz shall be reference)
	$> 10 \mu\text{F}$	100 Hz

Note 1 — The measuring voltage shall not exceed 3 percent of U_B or 5V, whichever is the smaller, unless otherwise prescribed in the relevant specification.

Note 2 — The tolerance on frequencies shall be ± 10 percent.

8.3.2.2 The accuracy of the measuring equipment shall be such that the error does not exceed:

- a) *for absolute capacitance measurements* : 10 percent of the rated capacitance tolerance or 2 percent absolute, whichever is the smaller;
- b) *for measurement of variation of capacitance* : 10 percent of the specified maximum change of capacitance.

In neither of cases (a) and (b) need the accuracy be better than the minimum absolute measurement error for (example 0.5 pF) prescribed in the relevant specification.

8.3.2.3 The relevant specification shall prescribe:

- a) the temperature for measurement if other than the standard atmospheric conditions for testing;
- b) the frequencies for measurement and the capacitance ranges over which they apply, if different from those specified in 8.3.2.1 ;
- c) the absolute measurement error, when applicable (for example, 0.5 pF) ;
- d) measuring voltage if different from those specified in 8.3.2.1 ; and
- e) the applied polarizing voltage, when applicable.

8.3.3 Tangent of Loss Angle

8.3.3.1 The tangent of the loss angle shall be measured, under the same conditions as those given for the measurements of capacitance at one or more frequencies taken from the list of frequencies specified in 8.3.2.1, as required in the relevant specification.

8.3.3.2 The measuring method shall be such that the error does not exceed 10 percent of the specified value or 0.000 1 whichever is greater.

8.3.4 Leakage Current

8.3.4.1 Before this measurement is made, the capacitors shall be fully discharged.

8.3.4.2 The leakage current shall be measured, unless otherwise prescribed in the relevant specification, using the direct voltage (U_R or U_C) appropriate to the test temperature, after a maximum electrification period of five minutes. The fully five minute electrification need not be applied if the specified leakage current is reached in a shorter time.

8.3.4.3 A steady source of power such as a regulated power supply shall be used.

8.3.4.4 The measurement error shall not exceed ± 5 percent or $0.1 \mu A$ whichever is the greater.

8.3.4.5 When prescribed in the relevant specification a $1\,000 \Omega$ protective resistor shall be placed in series with the capacitor to limit the charging current.

8.3.4.6 The relevant specification shall prescribe:

- a) the leakage current at a reference temperature of $25 \pm 2^\circ C$, and at other specified temperature;
- b) when necessary, the correction factor, if the measurements are made at a temperature other than $25^\circ C$ but within the range of temperature covered by the standard atmospheric conditions for testing;

- c) Electrification time if different from five minutes; and
- d) Whether or not a $1\ 000\ \Omega$ protective resistor shall be placed in series with the capacitor to limit the charging current as defined in 8.3.4.5.

8.3.5 Impedance — When required by the relevant specification the impedance shall be determined. The relevant specification shall prescribe:

- a) voltage;
- b) frequency as specified in the relevant specification;
- c) temperature;
- d) method of test and its accuracy;
- e) maximum value of impedance; and
- f) polarizing voltage, if necessary.

8.3.5.1 Method of measurement — A suitable method for measuring impedance is given in Appendix B.

8.3.6 Insulation Resistance

8.3.6.1 Before this measurement is made, the capacitors shall be fully discharged.

8.3.6.2 Unless otherwise specified the insulation resistance shall be measured at 500 V dc ± 10 percent or the rated voltage whichever is lower.

8.3.6.3 For test points B and C (see Table 1) when the case of the capacitor is non-metallic, or when the capacitor has a metallic case with an insulating sleeve, the test voltage shall be applied in one of the following ways:

- a) *Foil method* — A metal foil shall be closely wrapped around the body of the capacitor to within a distance from the terminations equal to approximately 1 mm/kV test voltage, with a minimum of 0.5 mm.
- b) *Method for capacitor with mounting devices* — The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 12.7 mm in all directions beyond the mounting face of the capacitor.
- c) *V-block method* — The capacitor shall be clamped in the through of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block. The clamping force shall be such as to maintain adequate contact between the capacitor and the block. The terminations shall be so positioned that the distance between the terminations and any point of the V-block is not less than:

- i) for cylindrical capacitors : the radius of the capacitor body minus the radius of the circumscribed circle of the terminations (the larger circle when the two terminations have different dimensions); and
- ii) for rectangular capacitors : half the smaller side of the capacitor body minus the radius of the circumscribed circle of the terminations (the larger circle when the two terminations have different dimensions).

Any out-of-centre positioning of the terminations at its emergence from the capacitor body shall be ignored.

8.3.6.4 The insulation resistance shall be measured after the voltage has been applied for 60 ± 5 seconds unless otherwise called for by the relevant specification.

8.3.6.5 When prescribed by the detail specification the temperature at which the measurement is made shall be noted and a correction made to the measured value, or to the setting of the test apparatus on go/no-go tests, correct the value to that at 25°C , in accordance with the correction factors prescribed in the sectional specification.

8.3.6.6 The relevant specification shall prescribe the following:

- a) The test points (see Table 1);
- b) The measuring voltage;
- c) The method of applying the test voltage, either (a) or (b) or (c) of 8.3.6.3;
- d) Time of electrification if more than 1 minute;
- e) Any special precaution to be taken during measurement;
- f) Any correction factor required for measurement over the range of temperatures covered by the standard testing conditions;
- g) The temperature of measurement if other than the standard atmospheric conditions for testing; and
- h) The minimum value of insulation resistance between the various test points (see Table 1).

8.3.7 Inductance — When required in the relevant specification, the inductance shall be determined.

The length of lead used to connect the capacitor to the test apparatus shall be minimum and the total length of the connecting leads shall not exceed the length of the body of the capacitor or 5.0 mm whichever is the greater.

NOTE — The usual requirement is that the inductance of the capacitor shall not be greater than the inductance of a straight round wire 0·2 mm in diameter and of a length equal to that of the capacitor and its terminations (see Fig. 2).

8.3.7.1 Method of measurement — A suitable method is given in Appendix B

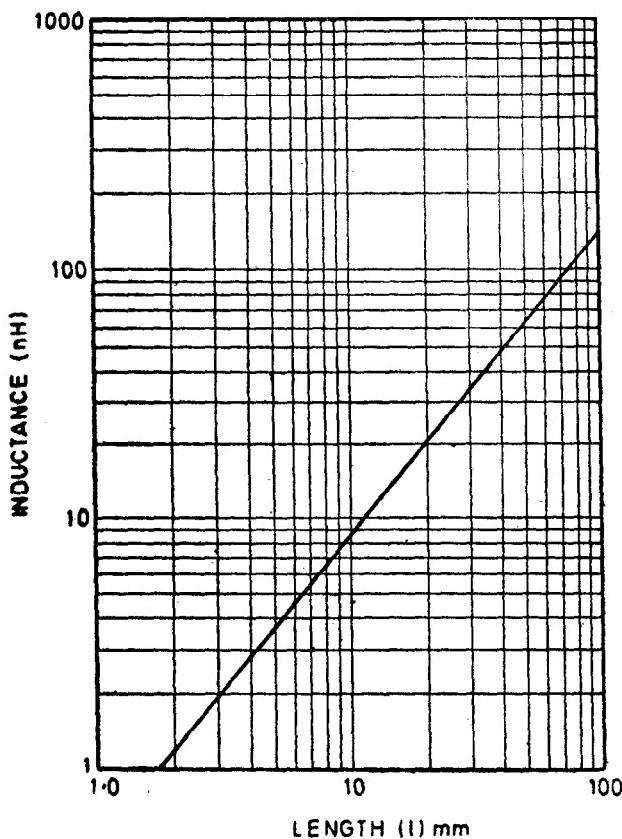


FIG. 2 INDUCTANCE OF STRAIGHT ROUND WIRE, 0·2 mm DIAMETER

8.3.8 Outer Foil Termination

8.3.8.1 The correct indication of the termination which is connected to the outside metal foil shall be checked in such a way that the capacitor is not damaged.

8.3.8.2 A suitable method is given in Appendix C,

8.3.9 Charge and Discharge

8.3.9.1 Initial measurements — The measurements specified in the relevant specification shall be made.

8.3.9.2 Test method — Suitable test circuits are shown in Fig. 3.

NOTE — The thyristor circuit has the advantage of high repetition rates and is free from troubles associated with dirty contacts and contacts bounce.

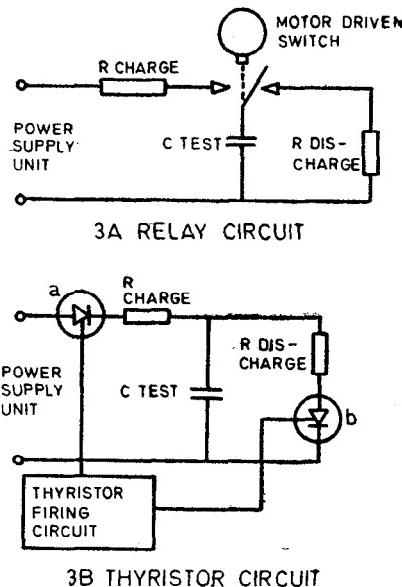


FIG. 3 TEST CIRCUIT FOR SURGE AND CHARGE AND DISCHARGE TESTS

The voltage and current waveforms across and through C test are approximately as shown in Fig. 4.

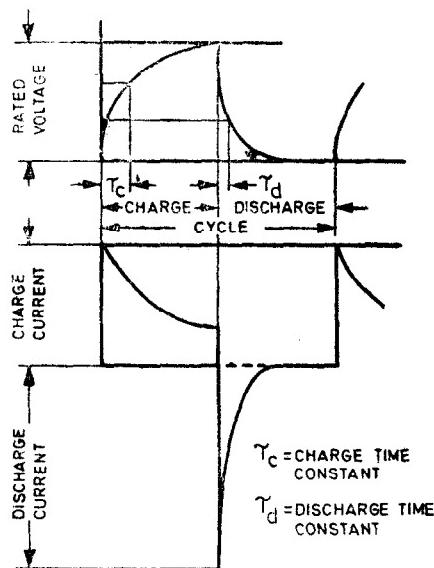


FIG. 4 VOLTAGE AND CURRENT WAVEFORMS

8.3.9.3 The following information shall be given in the relevant specification:

- the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitor under test;
- the discharge time constant arising from the resistance of the discharge circuit and the capacitor under test;
- the voltage to be applied during the charge period if different from the rated voltage;
- the number of cycles of test;
- the duration of the charge period;
- the duration of discharge period;
- the repetition rate (Hz); and
- temperature if different from standard atmospheric conditions for testing.

8.3.9.4 Final measurement — The measurements specified in the relevant specification shall be made.

8.3.10 Surge

8.3.10.1 Initial measurements — The measurements specified in the relevant specification shall be made.

8.3.10.2 Test method — The specimens shall be subjected to 1 000 cycles of the dc surge voltage. The ambient temperature during cycling shall be the applicable maximum temperature of the temperature severity. Each cycle shall consist of a 30-s surge voltage application followed by a 5·5 min discharge period. Voltage application shall be made through a resistor in series with the capacitor and the voltage source. For capacitors whose nominal capacitance is below 2 500 μF the resistor shall have a value of $1\ 000 \pm 100\Omega$. For capacitors whose nominal capacitance is 2 500 μF and above, the value of the resistor shall be determined from the following formula:

$$R = \frac{2.5 \times 10^6}{C}$$

where

R = resistance (Ω), and

C = capacitance (μF).

Each surge-voltage cycle shall be performed in such a manner that the capacitor is discharged through the applicable resistor at the end of the 30 seconds applications.

8.3.10.3 The following information shall be given in the relevant specification:

- a) the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitor under test;
- b) the discharge time constant arising from the resistance of the discharge circuit and the capacitor under test;
- c) the ratio of the surge voltage to the rated or category voltage (as appropriate);
- d) the number of cycles of test;
- e) the duration of the surge period;
- f) the duration of the discharge period;
- g) the repetition rate (Hz); and
- h) temperature if different from standard atmospheric conditions for testing.

8.3.10.4 Final measurements — The measurements specified in the relevant specification shall be made.

8.3.11 Self-Healing — This test shall be carried out in accordance with the method in Appendix D.

8.3.12 Variation of Capacitance with Temperature

8.3.12.1 Static method — Measurements of capacitance shall be made under the conditions prescribed in the relevant specification.

The capacitor shall be maintained at each of the following temperatures in turn:

- a) $25 \pm 2^\circ\text{C}$,
- b) lower category temperature $+ 0$
 $- 2^\circ$,
- c) $25 \pm 2^\circ\text{C}$,
- d) Temperatures, $+ 70^\circ \pm 2^\circ\text{C}$,
- e) upper category temperature $+ 2^\circ\text{C}$, and
 $- 0^\circ\text{C}$
- f) $25 \pm 2^\circ\text{C}$.

If required for a particular type of capacitor, the relevant specification shall prescribe whether thermal shock is to be avoided or whether a maximum rate of change of temperature is necessary.

Capacitance measurements shall be made at each of the temperatures specified above after the capacitor has reached thermal stability.

The condition of thermal stability shall be judged to have been reached when two readings of capacitance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The measurement of the actual temperature shall be made with a precision compatible with the requirements of the detail specification.

Care shall be taken during measurements to avoid condensation or frost on the surface of the capacitors.

In the case of quality conformance testing, the detail specification may prescribe a reduced procedure, for example, measurements (d), (f) and (g) covering the temperature range from 25°C to the upper category temperature.

8.3.12.2 Dynamic method — As an alternative to the static method, a dynamic plotting method may be employed. The capacitors shall be subjected to a slowly varying temperature.

A temperature-sensitive device shall be embedded in a dummy capacitor to be included with the capacitor under test in a manner that will ensure that the measured temperature is the same as that occurring in the capacitor under test. The capacitance shall be measured using a self-balancing bridge or comparator.

The output of the bridge or comparator shall be coupled to the Y-axis of a plotting table.

The output of the temperature sensing device shall be coupled to the X-axis of a plotting table.

The temperature shall be varied slowly enough to produce a uniform curve with no loop, at the lower or upper category temperature. The temperature shall be varied subsequently from 25°C to the lower category temperature, to the upper category temperature and to 25°C. The cycles shall be carried out.

This method may be employed only when it can be demonstrated that the results are the same as for the method employing stabilized temperatures.

In case of dispute, the static method shall be used.

8.3.12.3 Method of calculation

C_0 — capacitance measured at point (c);

t_0 — temperature measured at point (c);

C_1 — capacitance measured at the test temperature, other than at points (a), (c) and (f); and

t_1 — temperature measured in the test.

- a) *Temperature characteristic of capacitance* — The variation of capacitance as a function of temperature shall be calculated for all the values of C_1 as follows :

$$\frac{\Delta C}{C_0} = \frac{C_1 - C_0}{C_0}$$

The variation of capacitance is usually expressed in percent.

- b) *Temperature coefficient of capacitance and temperature cyclic drift of capacitance*

- i) *Temperature coefficient of capacitance (α)*

Temperature coefficient of capacitance (α) shall be calculated for all the values of C_1 as follows:

$$\alpha_1 = \frac{C_1 - C_0}{C_0 (t_1 - t_0)}$$

The temperature coefficient is usually expressed in parts per million per degree Celsius ($10^{-6}/^{\circ}\text{C}$)

- ii) *Temperature cyclic drift of capacitance* — The temperature cyclic drift of capacitance shall be calculated for the points of measurement of (a), (d) and (g) of 7.3.13.1 in the following manner:

$$\delta a = \frac{C_0 - C_a}{C_0}$$

$$\delta g_d = \frac{C_g - C_0}{C_0}$$

$$\delta g_a = \frac{C_g - C_a}{C_0}$$

as required by the relevant specification. The largest of these values is the temperature cyclic drift of capacitance.

The capacitance drift is usually expressed in percent.

8.3.13 Dielectric Absorption

8.3.13.1 Unless otherwise specified, the capacitor shall be charged at the dc voltage rating for 1 hour ± 1 minute. The initial surge current shall not exceed 50 milliamperes. At the end of this period, the capacitor shall be disconnected from the power source and discharged through a $5\Omega \pm 5$ percent resistor for 10 ± 1 seconds. The discharged resistor shall be disconnected from the capacitor at the end of the 10 second discharge period, and the voltage remaining on the capacitor (recovery voltage) shall be measured with an electrometer or other suitable device having an input resistance of 10 000 M Ω or greater. Recovery voltage shall be read at the maximum voltage within a 15 minutes period. The dielectric absorption shall be computed from the following formula:

$$d = \frac{V_1}{V_2} \times 100$$

where

d = percentage dielectric absorption,

V_1 = maximum recovery voltage, and

V_2 = charging voltage.

8.3.13.2 *Requirements* — The value shall be within the limits specified below:

Dielectric Materials

Polyester

Dielectric Absorption

0.60

Polystyrene

0.10

Polycarbonate

0.04

Dielectric absorption test is not applicable to values of 0.01 μF and less.

8.3.14 DC Resistance (Applicable to Feed through Patterns Only) — The dc resistance shall be measured directly using a kelvin bridge or indirectly using the voltmeter-ammeter method, ammeter-potentiometer method, or other suitable means. The point of contact shall be along the lead, where the lead is normally connected in an actual circuit, except for axial wire terminations, the contact shall be made 15.08 ± 3.20 mm from the insulator.

8.3.15 Insertion Loss — The specimens shall be tested and measurements shall be taken at a sufficient number of frequencies to permit the construction of smooth accurate curve of insertion loss versus frequency over a frequency range of 0.15 to 1 000 MHz, inclusive. Suggested frequencies are : 0.15, 0.5, 1, 2, 4, 8, 14, 20, 40, 80, 120, 200, 300, 400 and 1 000 MHz.

8.3.15.1 Requirements for feed through patterns — The insertion loss shall be not more than 6 dB. Dips below the value specified for an ideal capacitor of the same nominal capacitance value are permissible when tested at frequencies from 0.15 MHz up to that frequency at which the insertion loss of the capacitor under test becomes 60 dB. However at higher frequencies up to 1 000 MHz the insertion loss shall not fall below 60 dB. Deviations in the nature of dips in the curve shall be permitted. Such dips indicate a drop in insertion loss below that of an ideal capacitor followed by a rise in insertion loss, as frequency is increased faster than the rise that is characteristic of an ideal capacitor.

8.3.15.2 Requirements for patterns of bypass capacitors — The insertion loss shall be within 6 dB of the value of an ideal capacitor of the same nominal capacitance value up to 0.7 of the resonant frequency (F_R). From 0.7 F_R to F_R the insertion loss shall be at least equal to or better than the insertion loss of an ideal capacitor. From F_R to 1.4 F_R the insertion loss may be higher than the insertion loss of an ideal capacitor, but in no case 6 dB below the ideal curve. Beyond 1.4 F_R , the useful insertion loss decays rapidly.

8.3.16 Voltage Temperature Characteristic — The specimen shall remain under standard atmospheric conditions for 24 hours before commencement of this test. The capacitance shall be measured at the temperature and under the condition stated below:

- a) $20^\circ\text{C} \pm 1^\circ\text{C}$ with no polarising voltage;
- b) Minimum severity temperature + 0 with no polarising voltage;
— 2°C
- c) $20^\circ\text{C} \pm 1^\circ\text{C}$ with no polarising voltage (Reference);
- d) Maximum severity temperature + 2 with no polarising voltage;
— 0°C

- e) Maximum severity temperature + 2 with the rated voltage or
- 0°C 500 V whichever is less
- f) 20°C ± 1°C with the rated voltage or 500 V which is less ; and
- g) Minimum severity temperature + 0 with the rated voltage or
- 2°C 500 V whichever is less

The measurements at each temperature shall be recorded when two successive readings taken at 5 minutes intervals at that temperature indicate no change in capacitance.

NOTE — The capacitance shall also be measured at such other points between those stated above as are necessary to establish the true shape of the capacitance voltage temperature curves.

8.3.17 Reverse Voltage — The specimens shall be subjected to 3 V dc, applied in the reverse polarity direction for 125 ± 10 h. The ambient temperature during the test shall be 85°C. Capacitors shall be maintained at 85°C and dc rated voltage shall be applied in the forward polarity direction for an additional period of 125 ± 10 h. Capacitors shall then be returned to atmospheric conditions for testing. The following measurements shall than be made:

- a) Capacitance,
- b) Tangent of loss angle, and
- c) Leakage Current.

The requirements for these shall be as specified in the relevant specifications.

8.3.18 Stability at Low and High Temperatures — The capacitors shall be subjected to this test as given in the relevant specification and shall meet the requirements specified therein.

8.4 Physical and Mechanical Tests

8.4.1 Visual Examination — The capacitors shall be visually examined for compliance with the requirements of 6 and 7.

8.4.2 Dimensions — The dimensions shall be checked for compliance with those stated in the relevant specification.

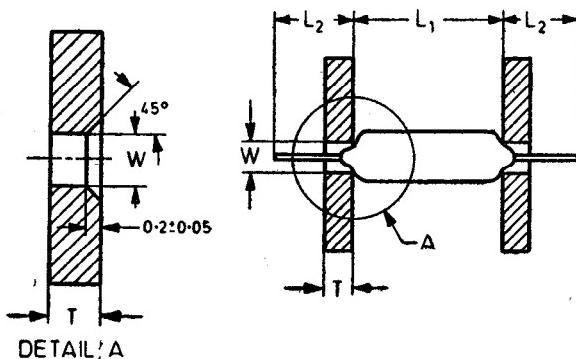
8.4.2.1 Measurement of the dimensions of a cylindrical components having two axial wire terminations

- a) **Length** — The length of the body shall be measured by inserting the terminations into slots (or holes) of two gauge plates and by moving the plates parallel to each other until the components body is clamped without deforming the body or the termination.

The plates shall be considered sufficiently close to parallel if, allowing for the size of plate and the distance between the component and the measuring device, the error in measurement due to this cause does not exceed 0.2 mm.

Alternative methods of measurement are given in Methods 1 and 2 (see Fig. 5 and 6).

Method 1



The length of the body is equal to the measured length L_1 .
The length of the termination is equal to L_2 .

FIG. 5 GAUGE PLATE FOR COMPONENTS HAVING AXIAL WIRE TERMINATIONS (EXCEPT COMPONENTS MENTIONED IN METHOD 2)

The width of the slot W (or the diameter of the hole) in the gauge plate shall depend on the diameter of the wire termination in the manner given in Table 2.

TABLE 2 WIDTH OF THE SLOT

NOMINAL DIAMETER OF WIRE TERMINATIONS	W
(1) mm	(2) mm
Up to and including 0.45	0.8 \pm 0.02*
0.45 up to and including 0.7	1.0 \pm 0.02*
0.7 up to and including 0.9	1.2 \pm 0.02*
0.9 up to and including 1.15	1.5 \pm 0.02*
1.15 up to and including 1.32	1.8 \pm 0.02*
1.32 up to and including 2.0	3.0 \pm 0.02*

*The tolerance need only be maintained in the locality of the point where the termination will be during the measurement.

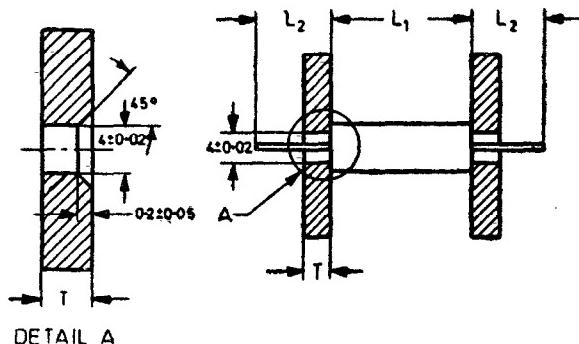
Method 2

FIG. 6 GAUGE PLATES FOR COMPONENTS WITH A DIAMETER OF 5 mm AND OVER HAVING AXIAL TERMINATIONS AND WITH GLASS METAL SEALS OR WITH DISCONTINUITIES IN THE WIRE TERMINATIONS

If there is a discontinuity in the wire termination, for example, on components with welded terminations outside the case and on components provided with glass seals, the thickness of the gauge has no significance in the measurement of length. The length of the component shall be taken as the distance between the inside faces of the gauge plates L_1 , the length of the termination is equal to L_2 .

The width of the slot (for the diameter of the hole) in the gauge plate shall be 4.00 ± 0.02 mm.

NOTE— This tolerance need only be maintained in the locality of the point where the termination will lie during measurement.

- b) *Maximum length of the termination covered by coating material*— When the terminations are inserted in the gauge plates and the component is clamped as prescribed in 8.4.2.1(a) no coating material shall extend beyond the gauge plates. The thickness T of the gauge plates shall be specified in the relevant detail specifications.

NOTE— Recommended values for gauge plate thicknesses are 1.5 ± 0.05 mm for components for use on single sided printed wiring board and 4.00 ± 0.05 mm for components for other applications.

- c) *Method for checking the overall diameter*— For a given diameter the component shall pass through a straight tube, of which the internal diameter is equal to the maximum prescribed body diameter ± 0.1 mm with a tolerance of $-0/+0.05$ mm and the length is the maximum prescribed body length for that component. The component shall pass through the gauge by its own mass.

The maximum diameter of the component as given by the manufacturer shall take into account the irregularities in the shape of the body such as bow and wire wrapping as part of the terminations of ceramic capacitors, etc.

8.4.2.2 Measurement of a component having radial wire terminations (Under consideration).

8.4.3 Mass — Where prescribed in the relevant specification, the specimen shall be weighed. The mass shall not be greater than the maximum prescribed in the relevant specification.

8.4.4 Robustness of Terminations — The capacitors shall be tested to determine the ability of their terminations to withstand forces such as tensile, bending, torsion and torque, in accordance with IS : 9000 (Part 19/Sec 1 to 5)-1978*.

Note—Tests for bending and torsion shall not be applied if the relevant specification describes the terminations as rigid.

8.4.4.1 Tensile — This test shall be carried out in accordance with IS : 9000 (Part 19/Sec 1)-1978* the loading force being as given in Table 3.

TABLE 3 LOADING FORCE (FOR EACH TERMINATION)

a)	FOR WIRE TERMINATIONS			CORRESPONDING NOMINAL DIAMETER OF ROUND WIRE D			LOAD N
	GROSS-SECTIONAL AREA OF WIRE A mm			mm			
	A	<	0·05				
0·05	<	A	<	0·07	0·25	<	d < 0·30 2·5
0·07	<	A	<	0·20	0·30	<	d < 0·50 5·0
0·20	<	A	<	0·50	0·50	<	d < 0·80 10·0
0·50	<	A	<	1·20	0·80	<	d < 1·25 20·0
		>	1·20	1·25	<	d	40·0

b) For other types of terminations : 20 N

Note — The body of the capacitor shall be clamped in such a way that the coating, if any, of the capacitor does not peel off during the test.

*Basic environmental testing procedures for electronic and electrical items: Part 19
Test for robustness of terminations and integral mounting devices,

Section 1 Tensile test.

Section 2 Thrust test.

Section 3 Bending test.

Section 4 Torsion test.

Section 5 Torque test.

There shall be no visible damage to the capacitor after this test.

8.4.4.2 Bending — This test shall be carried out in accordance with IS : 9000 (Part 19/Sec 3)-1978*. Care shall be taken to ensure that the bend occurs at a point 6 mm from the point of emergence of the wire or strip from the capacitor and around a radius of 0·75 mm suitable arrangement to ensure this requirement is shown in Fig. 7.

Each termination shall withstand two consecutive bends without any damage to the capacitor.

NOTE — In the case of capacitors with axial termination this test shall be carried out on one half of termination while on the other half torsion test (see 8.4.4.3) shall be carried out.

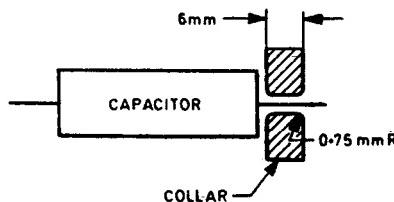


FIG. 7 ARRANGEMENT FOR BEND TEST

There shall be no visible damage to the capacitor after this test.

8.4.4.3 Torsion (For axial terminations only) — This test shall be carried out in accordance with IS : 9000 (Part 19/Sec 4)-1978†. Two successive rotations of 180° shall be performed.

There shall be no visible damage to the capacitor after this test.

8.4.4.4 Torque (For nuts, threaded terminations and integral devices) — This test shall be carried out in accordance with Section 5 of IS : 9000 (Part 19/Sec 5)1978‡, using one of the following two severities, as specified in the relevant specification :

Basic environmental testing procedures for electronic and electrical items : Part 19 Test for robustness of terminations and integral mounting devices,

*Section 3 Bending test.

†Section 4 Torsion test.

‡Section 5 Torque test.

Nominal Thread Diameter, mm

		2·6	3·0	3·5	4·0	5·0	6·0
Torque Nm	Severity 1	0·4	0·5	0·8	1·2	2·0	2·50
	Severity 2	0·2	0·25	0·4	0·6	1·0	1·25

There shall be no visible damage to the capacitor after this test.

8.4.5 Soldering

8.4.5.1 Solderability — The capacitors shall be subjected to this test either using the solder bath method, or the soldering iron method, or the solder globule method, in accordance with IS : 9 000 (Part 18/Sec 1) - 1981*. Where the solder bath method is used, the depth of immersion from the seating plane or component body shall be as follows:

- a) Capacitors specifically designed for printed circuit applications
 $2\cdot0 + 0$ mm using a thermal insulating screen of $1\cdot5 \pm 0\cdot5$ mm
 $- 0\cdot5$ thickness.
- b) Capacitors for general purpose application : $3\cdot5 + 0$
 $- 0\cdot5$ mm

The terminations shall not be greased. Non-activated flux shall be used.

The test shall be applied at any point on the terminations otherwise specified in the relevant specification.

The period of recovery shall be 1 to 2 hours.

Requirements — The immersed part of the termination must be at least 95 percent covered with a regular coating of solder.

When the solder bath method is not applicable the relevant specification shall define both the test conditions and the requirements.

8.4.5.2 Resistance to soldering heat — The capacitors shall be subjected to the procedure for resistance to soldering heat in accordance with IS : 9000 (Part 18/Sec 2) 1981†, with the following requirements:

Basic environmental testing procedures for electronic and electrical items : Part 18 Solderability test,

*Section 1 Solderability test of wire and tag terminations.

†Section 2 Resistance of items to soldering heat.

a) Capacitors specifically designed for printed circuit applications:

Method 1 A

Depth of immersion from the seating plane

2.5 +0
-0.5 mm

b) Capacitors for general purpose application:

Method 1 B

Depth of immersion from the component body :

3.5 +0
-0.5 mm

The period of recovery shall be not less than 1 hour nor more than 2 hours.

8.4.5.3 When the test procedures have been carried out the capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

8.4.5.4 The capacitors shall then be measured as prescribed in the relevant specification.

8.4.6. *Vibration*

8.4.6.1 The measurements prescribed in the relevant specification shall be made.

8.4.6.2 The capacitors shall be subjected to the procedure as specified in IS : 9000 (Part 8)-1981* using the mounting, the method and degree of severity as specified in the relevant specification. If called for in the relevant specification measurements shall be carried out during the test.

8.4.6.3 After the test the capacitors shall be visually examined.

8.4.6.4 The measurements prescribed in the relevant specification shall then be made.

8.4.7 *Bump*

8.4.7.1 The measurements prescribed in the relevant specification shall be carried out.

8.4.7.2 The capacitors shall be subjected to the procedure as specified in IS: 9000 (Part 7/Sec 2)-1979† using the mounting and the preferred degree of severity for capacitors unless otherwise specified in the relevant specification.

Basic environmental testing procedures for electronic and electrical items :

*Part 8 Vibrations (sinusoidal) test.

†Part 7 Impact test, Section 2 Bump.

8.4.7.3 After the test the capacitors shall be visually examined.

8.4.7.4 The tests prescribed in the relevant specification shall be carried out.

8.4.8 Shock — The shock test shall be carried out as outlined in Appendix E.

8.4.9 Acceleration — The acceleration test shall be carried out in accordance with Appendix F.

8.4.10 Vent

8.4.10.1 The specimen shall be subjected to ac test current at 50 to 60 Hz in accordance with the details given below. The vent shall operate within 5 minutes. If the capacitor opens or short circuits and the vent has not operated, additional capacitors shall be selected and subjected to this test.

<i>Nominal Capacitance</i> μF	<i>Test Current</i> A (rms) (inclusive)
up to 3 000 inclusive	10 to 100
3 001 to 20 000 inclusive	85 to 150
over 20 000	100 to 175

8.4.10.2 There shall be no explosive expelling of the contents. Distribution shall occur only at the vent; the case or and seal shall not otherwise rupture.

8.4.11 Scintillation

8.4.11.1 The specimen shall be monitored in a test circuit capable of detecting short term fluctuations of capacitance of at least 0·01 percent at a frequency of not less than 1 MHz. The capacitor shall be subjected for 30 minutes to a direct potential equal to half the rated voltage of the capacitor and superimposed alternating voltage having a rms value of 20 V at the measuring frequency. The capacitance shall be monitored in the last 10 minutes of this period, the ambient temperature being constant $\pm 2^\circ\text{C}$ during that time.

8.4.11.2 Unless otherwise specified, there shall be no random variations of frequency.

8.5 Climatic Tests

8.5.1 Climatic Sequence — In the climatic sequence, an interval of maximum 3 days is permitted between any of the tests except that the cold test shall be applied immediately after the recovery period for the first cycle of the damp heat cyclic test.

8.5.1.1 Initial measurements — The measurements prescribed in the relevant specification shall be made.

8.5.1.2 Dry heat — The capacitors shall be subjected to dry heat test in accordance with IS: 9000 (Part 3/Sec 3)-1977* for 16 h, using the degree of severity of the upper category temperature, as prescribed in the detail specification. Throughout the period of exposure the category voltage shall be applied to half the number of specimens. While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the relevant specification shall be made.

After specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing, for 2 h.

8.5.1.3 Damp heat cyclic first cycle — The capacitors, other than those of category -/-04, shall be subjected to this test in accordance with IS : 9000 (Part 5/Sec 1 and 2) - 1981† for one cycle of 24 h, using the severity prescribed in the relevant specification.

After recovery the capacitors shall be subjected immediately to the cold test.

8.5.1.4 Cold — The capacitors shall be subjected to cold test in accordance with IS : 9000 (Part 2/Sec 3) - 1977‡ for 2 h, using the degree of severity of the lower category temperature as prescribed in the relevant specification. During the test 10 minutes of the period of exposure the rated voltage shall be applied to the specimens of 8.5.12. While still at the specified low temperature and at the end of the period of low temperature, the measurements prescribed in the relevant specifications shall be made.

After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 2 h.

8.5.1.5 Low air pressure — The capacitors shall be subjected to low air pressure test in accordance with IS : 9000 (Part 13) - 1981§ using the appropriate degree of severity prescribed in the relevant specification. The duration of the test shall be 5 minutes, unless otherwise stated in the relevant specification.

Basic environmental testing procedures for electronic and electrical items :

*Part 3 Dry heat test, Section 3 Non-heat dissipating items with gradual change of temperature.

†Part 5 Damp heat (cyclic), Section 1 16 + 8 h cycle; Section 2 12 + 12 h cycle.

‡Part 2 Cold, Section 3 Non-heat dissipating items with gradual change of temperature.

§Part 13 Low air pressure test.

The relevant specification shall prescribe:

- a) duration of test, if other than 5 min;
- b) temperature ; and
- c) degree of severity.

While still at the specified low pressure a direct voltage shall be applied as prescribed in the relevant specification. This direct voltage shall be the rated voltage and shall be applied for the last 1 min of the test period, unless otherwise prescribed in the relevant specification.

During and after the test there shall be no evidence of permanent breakdown, flashover, harmful deformation of the case or seepage of impregnant.

8.5.1.6 Damp heat cyclic remaining cycles — The capacitors, other than those of category -/-04, shall be subjected to this test in accordance with IS : 9000 (Part 5/Sec 1 and 2)-1981* for the following cycles of 24 h, using the severity prescribed in the relevant specification.

8.5.1.7 Final measurements — After the prescribed recovery the measurements prescribed in the relevant specification shall be made.

8.5.2 Damp Heat (long term)

8.5.2.1 The measurements prescribed in the relevant specification shall be made.

8.5.2.2 The capacitors shall be subjected to the procedure of IS : 9000 (Part 4)-1979† using the appropriate degree of severity. With the exception of electrolytic capacitors, within 15 min after removal from the chamber; the voltage proof test shall be carried out at Test point A only, using the rated voltage.

8.5.2.3 After recovery the capacitors shall be visually examined. There shall be no visible damage.

8.5.2.4 The measurements prescribed in the relevant specification shall then be made.

Basic environmental testing procedure for electronic and electrical items:

*Part 5 Damp heat (cyclic),
Section 1 16 + 8 h cycle; Section 2 12 + 12 h cycle.

†Part 4 Damp heat (steady state)

8.5.3 Rapid Change of Temperature — The measurements specified in the relevant specification shall be made. The capacitors shall be subjected into the procedure of IS : 9000 (Part 14)-1978*. After recovery, the capacitors shall be visually examined. The measurements prescribed in the relevant specification shall then be made.

8.6 Endurance

8.6.1 The measurement prescribed in the relevant specification shall be made.

8.6.2 The capacitors shall be submitted to an endurance test. The duration of this test, the value(s) of the applied voltage and the chamber temperature(s) at which it should be conducted, shall be prescribed in the relevant specification.

8.6.3 A capacitor shall be considered to have failed when the requirements of the relevant specification during or at the end of the test are not satisfied.

8.6.4 The capacitors shall be placed in the test chamber in such a manner that:

- a) During ac testing no capacitor is within 25 mm of any other capacitor.
- b) During dc testing no capacitor is within 5 mm of any other capacitor.

The capacitor shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than 3°C from the specified temperature of the chamber, at any point where the capacitors may be placed.

8.6.5 After the specified period, the capacitors shall be allowed to recover under standard atmospheric conditions for testing.

8.6.6 The capacitors shall then be visually examined. There shall be no visible damage.

8.6.7 The measurements prescribed in the relevant specification shall then be made.

*Basic environmental testing procedure for electronic and electrical items : Part 14
Change of temperature.

8.7 Storage

8.7.1 Storage at High Temperature — The capacitors shall be stored in accordance with IS : 9001 (Part 14)-1981*. The measurements prescribed in the relevant specification shall be made using the following severities.

Temperature : Upper category temperature
Duration : 96 ± 4 h

After recovery for at least 16 hours, the measurements prescribed in the relevant specifications shall be made.

8.7.2 Storage at Low Temperature — The measurements prescribed in the relevant specification shall be made.

The capacitors shall be stored at — 40°C for either a period 4 h after thermal stability has been reached, or for 16 h.

After recovery for at least 16 h the measurements prescribed in the relevant specification shall be made.

8.8 Mould Growth — The capacitors shall be subjected to the mould growth test in accordance with IS : 9000 (Part 10)-1980† and shall satisfy the requirements specified in the relevant specification.

8.9 Salt Mist — The capacitors shall be subjected to the salt mist test in accordance with IS : 9000 (Part 11)-1984‡. The duration of exposure shall be as stated in the relevant specification. After the expiry of the period of exposure, the capacitors shall be removed from the chamber and visually examined for any apparent deterioration, such as corrosion and damage and illegibility of marking.

8.10 Container Sealing — This test is applicable to the sealed type capacitors only. The capacitors shall be subjected to the appropriate sealing test as specified in the relevant specification in accordance with IS : 9000 (Part 15/Sec 3)-1982§. The requirements to be met with, shall be stated in the relevant specification.

8.11 Resistance to Solvents — The capacitors shall be subjected to this test in accordance with IS : 9000 (Part 20)-1979|| and shall satisfy the requirements specified in the relevant specification.

8.12 Resistance to Steam (Applicable to Non-hermetically Sealed Patterns only) — The capacitors shall be exposed to a saturated steam atmosphere of 35 kPa for a period of 90 min the terminals shall not be welded, soldered or disfigured. There shall be no evidence of unwrapping of the capacitor case or sleeve or other damage to the case.

*Guidance for environmental testing : Part 14 Storage tests.
Basic environmental testing procedures for electronic and electrical items.

†Part 10 Mould growth test.

‡Part 11 Salt mist test.

§Part 15 Sealing tests, Section 3 Container sealing, gas leakage.

||Part 20 Resistance to cleaning solvents and permanence of markings.

A P P E N D I X A

(*Clause 0.5*)

ENDURANCE TEST

A-1. INITIAL MEASUREMENTS

A-1.1 The measurements prescribed in the detail specification shall be made.

A-2. The capacitors shall be subjected to tests as follows :

- a) *dc Tests* — See Section 3 of IS : 9000 (Part 3)-1977*.
- b) *ac Tests* — See Section 3 or 5 of IS : 9000 (Part 3)-1977*.
- c) *Pulse Tests* — See Section 3 or 5 of IS : 9000 (Part 3)-1977*.

A-3. The detail specification shall prescribe:

- a) duration of the test (for example, hours or number of pulses);
- b) temperature of the test (for example, room ambient, rated or upper category temperature); and
- c) voltage to be applied (*see also A-4*).

A-4. Unless otherwise specified in the relevant specification the voltage to be applied during the test shall be selected from the following:

- a) *dc Tests* — The test will be carried out at a multiplying factor times the rated voltage (dc) at up to the rated temperature. The temperature of the test, the value of the multiplying factor and the derating factor for tests at the upper category temperature shall be specified in the relevant specification.
- b) *ac Tests* — The test will be carried out normally at 50 Hz and at a multiplying factor times the rated voltage (ac) at up to the rated temperature. The temperature of the test, the values of the multiplying factor and the derating factor for tests at the upper category temperature shall be specified in the relevant specification.
- c) *ac Tests (Constant Current)* — This test shall be carried out with a current applied in accordance with 2.2.1(b). The temperature of the test, the value of current and frequency shall be specified in the relevant specification.

*Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test, Section 3 Non heat dissipation items with gradual change of temperature,

For ease of testing the test may be defined as a voltage at a specific frequency to be applied to a group of capacitors in parallel.

- d) *ac Tests (Constant VA, or Power Dissipation)* — This test shall be carried out with VA, or power applied in accordance with 2.2.1(c). The temperature of this test, the value of VAr or power, and the frequency shall be specified in the relevant specification.

For ease of testing the test may be defined as a voltage at a specific frequency to be applied to a group of capacitors in parallel.

An alternative to this test is a thermal stability test (*see A-10*).

- e) *Pulse Tests* — This test shall be carried out with pulses applied in accordance with 2.2.2 and as specified in the relevant specification. Guidance on the carrying out of pulse tests is given in Appendix G.
- f) ac or pulse tests with superimposed dc tests (b) to (e) may be carried out with superimposed dc as required by the relevant specification.

An example of a test circuit suitable for electrolytic capacitors is as given in Fig. 8.

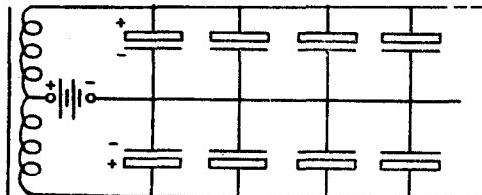


FIG. 8 TEST CIRCUIT FOR ELECTROLYTIC CAPACITORS

A-5. The detail specification shall prescribe:

- duration of the test (for example, hours or number of pulses);
- temperature of the test (for example, room ambient, rated or upper category temperature); and
- voltage to be applied (*see also A-4*).

A-6. The capacitors shall be placed in the test chamber in such a manner that no capacitor is within the following distances of another capacitor

- dc tests 5 mm
- ac or pulse tests 25 mm

A-7. THERMAL STABILITY TEST

An alternative to an endurance test in accordance with A-4(d) is a thermal stability test.

The capacitor shall be energised with a specified factor times the rated VAr or power dissipation at the rated temperature and period as specified in the detail specification. A test for thermal stability shall be carried out by measuring the temperature rise as a function of time over the last part of the specified period. The temperature rise shall remain constant within specified limits.

A P P E N D I X B

(Clauses 8.3.5.1 and 8.3.7.1)

MEASUREMENT OF IMPEDANCE AND INDUCTANCE OF FIXED CAPACITORS

B-1. IMPEDANCE

B-1.1 The basic method of measurement of impedance of a capacitor is to pass a known current through it and to measure the voltage across it. At frequencies of 100 kHz or less, this is relatively simple, but at higher frequencies, care is necessary by the use of coaxial cables and screening to avoid spurious coupling.

B-1.1.1 The basic circuit diagram is shown in Fig. 9.

B-1.1.2 The impedance of the capacitor be given by:

$$\begin{aligned} Z_c &= R_c + j \left(wL_c - \frac{1}{wC} \right) \\ &= R_c + jX_c \end{aligned}$$

where

Z_c = impedance of the capacitor at the frequency of measurement;

R_c = effective series resistance of the capacitor;

$w = 2\pi f$, f being the frequency of measurement;

L_c = inductance of the capacitor; and

C = capacitance of the capacitor at the frequency of measurement.

Using the notation of Fig. 9.

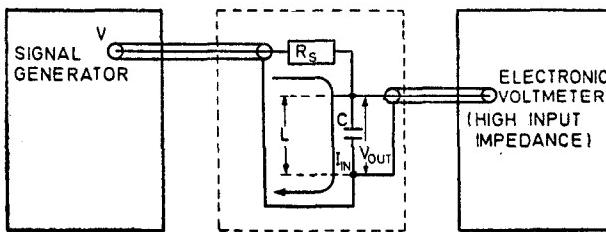
$$I_{in} = \frac{V_{in}}{R_s + Z_c}$$

$$V_{out} = I_{in} Z_c = \frac{V_{in} Z_c}{R_s + Z_c}$$

Therefore

$$Z_e = \frac{V_{out} R_s}{(V_{in} - V_{out})}$$

This equation can be used to determine the impedance at any frequency.



C = capacitor under test,

R_s = non-inductive resistor approximately equal to the output impedance of the signal generator (normally $50\ \Omega$ or $75\ \Omega$),

L_s = specified length (terminal wire and body) at which measurement is made,

V_{in} = voltage output of the signal generator with the measuring circuit connected,

I_{in} = current in the measuring circuit, and

V_{out} = voltage measured across the capacitor as indicated by the electronic voltmeter.

FIG. 9 METHOD OF DETERMINATION OF IMPEDANCE, RESONANT FREQUENCY OR INDUCTANCE OF CAPACITORS

B-2. INDUCTANCE

B-2.1 Resonance Frequency Method — At resonance

$$\omega L_c = \frac{1}{\omega_e} \quad \text{and}$$

$$Z_e = R_c$$

Thus Z passes through a minimum at the resonant frequency $\omega_0 = 2\pi f_0$. This is a convenient way of determining the inductance which is given by

$$L_c = \frac{1}{\omega_0 Z_e}$$

The resonant frequency as a function of capacitance and inductance is shown in Fig. 10.

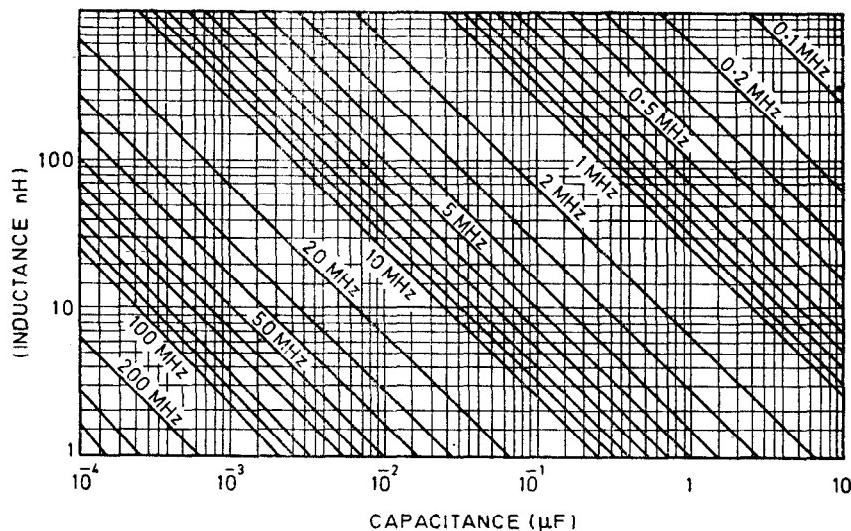


FIG. 10 RESONANT FREQUENCY AS A FUNCTION OF INDUCTANCE AND CAPACITANCE

B-2.2 Impedance Method — If the impedance of the capacitor is measured at a frequency above resonance such that:

$$\omega L_c = \frac{10}{\omega_c}$$

Hence

$$\frac{1}{\omega^2 L_c C} = \frac{1}{10}$$

Since

$$Z_c = R_c + j\omega L_c \left(1 - \frac{1}{\omega^2 L_c C} \right)$$

$$= R_c + j\omega [L_c (0.9)]$$

Assuming that

$$R_c \leq w L_c$$

$$Z_c \approx 0.9 w L_c$$

From which

$$L_c \approx \frac{Z_c}{0.9 \omega}$$

It should be noted that this equation is true at a frequency 3·16 times the resonant frequency; at higher frequencies the coefficient varies between 0·9 and 1. Where the resonant frequency is not known accurately at least 4 times the resonant frequency should be used and a coefficient of 0·95 employed.

A typical impedance frequency characteristic is shown in Fig. 11.

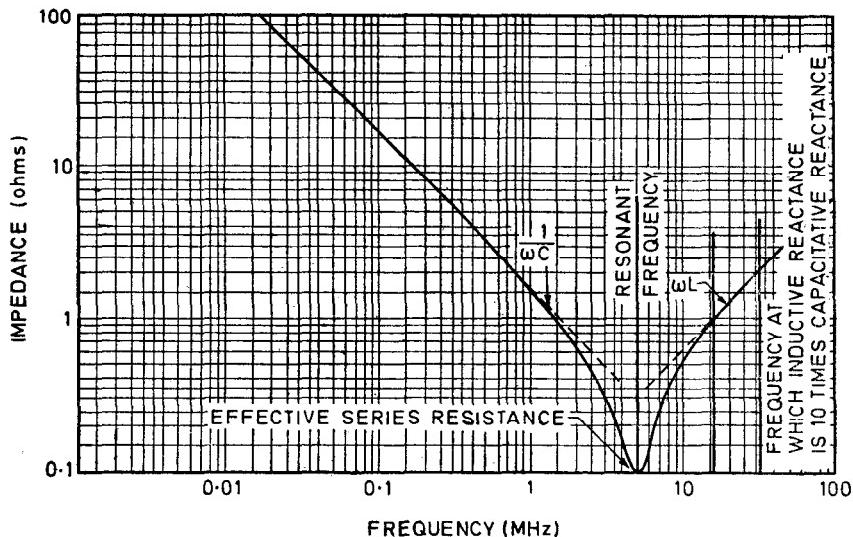


FIG. 11 TYPICAL CAPACITOR IMPEDANCE/FREQUENCY CHARACTERISTIC

Measuring methods for inductance of mica capacitors

Method 1

The length of the leads required to connect the capacitor to the test apparatus shall be a minimum, and the total length of the connecting leads shall not exceed the length of the body of the capacitor.

The measuring frequency shall be so chosen that the inductive reactance is at least ten times the capacitive reactance.

The detail specification shall prescribe the maximum inductance, if different from the requirement that the inductance shall not be greater than the inductance of a straight round wire 0·2 mm in the diameter and of a length equal to the capacitor and its terminations.

Method 2

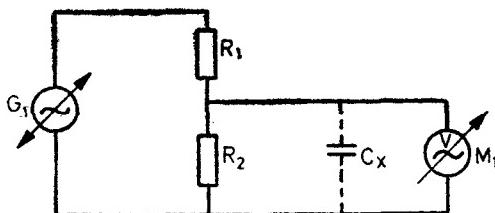


FIG. 12

R_1 and R_2 are situated in a coaxial line matched to the impedance Z_{out} of the generator G_1 .

$$R_1 = 0.95 Z_{\text{out}}$$

$$R_2 = 0.05 Z_{\text{out}}$$

$$Z_{\text{out}} = \text{rated impedance of } G_1$$

a) Nominal inductance L_o

For the mica capacitors covered by this standard an acceptable approximation for the calculation of the nominal inductance is 1nH/mm of the capacitor and lead length between the test terminals.

b) Operation sequence

- 1) The maximum inductance (L_n) of the capacitor is calculated according to the formula

$$L_n = l \cdot L_o \quad l = \text{capacitor length (nm)} \text{ [see (a)]}.$$

$$L_o = 1 \text{ nH/mm capacitor length [see (a)]}.$$

- 2) The minimum resonant frequency of the capacitor is calculated according to the formula

$$f_r = \frac{1}{2\pi\sqrt{L_n \cdot C_x}} \quad L_n = \text{nominal capacitor inductance.}$$

C_x = true capacitance.

- 3) The capacitor is connected to the terminals or an adapter conforming to the test circuit given above. The frequency of the signal generator shall be set at the value calculated in (b)(2) above and the reading of the voltmeter noted.

The frequency is then increased to about 1.5 times the value of (b)(2) above and the change of the voltmeter reading noted. As an alternative to the voltmeter and signal generator, an oscilloscope and sweep generator can be used, the centre frequency being equal to f .

c) *Requirement*

The voltage minimum shall be indicated above the minimum frequency f_r .

NOTE — The voltage minimum for a poor capacitor appears at a much lower frequency.

A P P E N D I X C

(Clause 8.3.8.2)

TEST FOR OUTER FOIL TERMINATION

C-1. The correct indication of the termination which is connected to the outside metal foil shall be checked in such a way that the capacitor is not damaged. A suitable method is shown in Fig. 13.

C-2. The frequency of the generator may be from 50 Hz to a few thousands Hz and shall be so chosen as to give a clear result of the measurement, the most appropriate value being dependent on the type of capacitor under test. The voltage shall be of the order of 10 V. The voltmeter shall have an input impedance of not less than $1 \text{ M}\Omega$. The stray capacitance of the wiring shall be kept low.

C-3. With the switch in position 1, the deflection of the voltmeter shall be markedly less than the switch in position 2.

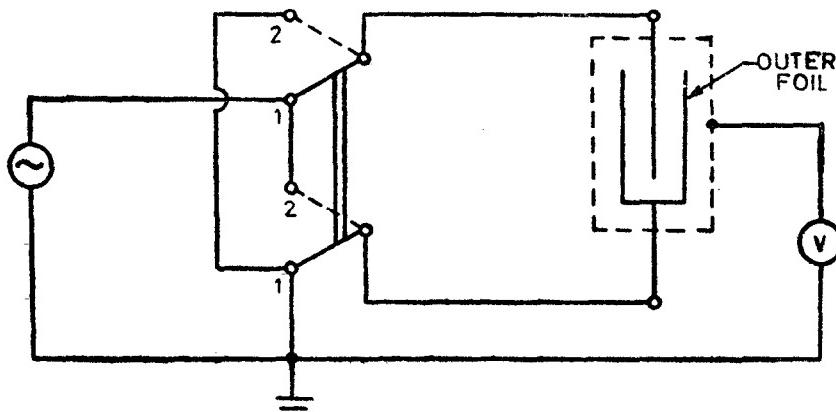


FIG. 13 ARRANGEMENT FOR CHECKING OUTER FOIL INDICATION

A P P E N D I X D

(Clause 8.3.11)

SELF-HEALING TEST**D-1. TEST SEVERITY**

D-1.1 The specimens shall be subjected to rated voltage and applicable maximum temperature of the temperature severity for $2\ 000 \pm 72$ hours. The temperature when measured at any time of the body of any capacitor, shall be the upper category temperature. Radiation shall not be used as a means of heating the chamber. The voltage shall be applied to each capacitor through its individual current-limiting resistor as determined from the following formula:

$$R = \frac{0.025}{C}$$

where

 R = resistance (Ω), and C = nominal capacitance (F).

NOTE — The actual current-limiting resistor employed shall have a resistance value within ± 10 percent of the calculated value (R). However, R need not exceed $2\ M\Omega$.

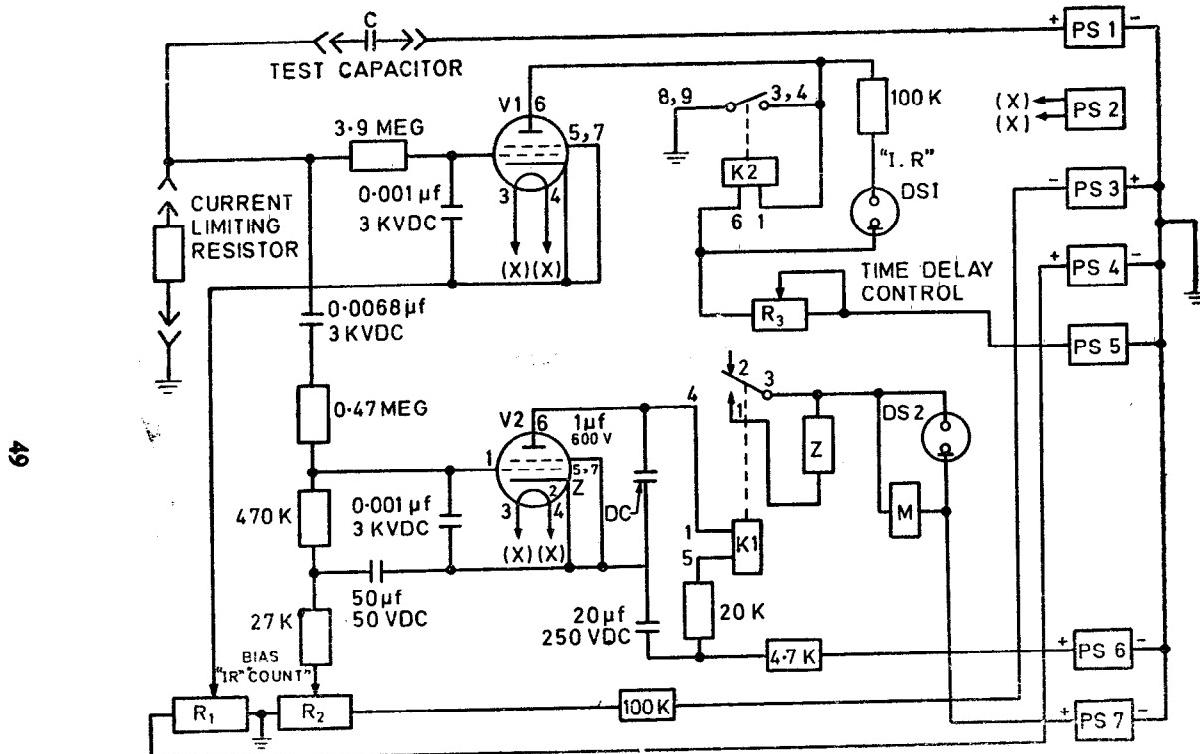
During this period, capacitors shall be monitored continuously for momentary breakdown and long periods of low insulation resistance by means of a fault-count monitoring circuit similar to the typical monitoring circuit shown in Fig. 14 and meeting the requirements outlined therein. After the specified monitoring period, capacitors shall be returned to standard test conditions and insulation resistance and capacitance shall be measured.

D-1.2 Requirements

D-1.2.1 Breakdown — The total number of counts registered on the 'Momentary-breakdown counter' shall not exceed $6 C$ or 1, whichever is greater (where C is the nominal capacitance in μF of the specimen). The total number of counts for any single capacitor in a 24-hours period shall not exceed $4 C$ or 1, whichever is greater.

D-1.2.2 Period of Low Insulation Resistance — The period of low insulation resistance shall not exceed 2 minutes for any specimen tested, as recorded by the 'Insulation Resistor Monitor'.

D-1.2.3 The insulation resistance (terminal-to-terminal and terminal-to-case) shall be measured and it shall be as specified in the relevant specification. The capacitance shall be measured and it shall not change more than 10 percent unless otherwise specified.



\mathcal{Z} = arc suppressor; M = counter; $DS1, DS2$ = lamp; $K1$ = relay; $K2$ = thermal relay; and
 PS = power supply.

NOTE — All resistors consuming $1W \neq 5$ percent, except as noted (WW = wirewound).

FIG. 14. TYPICAL MONITORING CIRCUIT FOR SELF-HEATING TEST

D-2. MONITORING CIRCUIT

D-2.1 The monitoring circuit shall have the capability of detecting and recording periods of low insulation resistance of at least 2 minutes and simulated breakdown pulses of the following parameters:

- | | |
|--------------------|--|
| a) Pulse width | 3 ms, <i>Max</i> |
| b) Amplitude | 5.0 volts, <i>Max</i> |
| c) Repetition rate | 15 pulses per second (pps), <i>Min</i> |

Fault-count monitoring circuit calibration shall be accomplished periodically by using a calibration standard having a minimum output impedance of 60Ω designed to accurately produce a series of signals meeting the above parameters.

D-3. OPERATING INSTRUCTIONS

D-3.1 Equipment

D-3.1.1 Indicator Station Panel Capacitors

- a) Momentary breakdown counter:
 - 1) Electromechanical counter, and
 - 2) 'COUNT BIAS' control.
- b) LOW IR detector:
 - 1) IR red lamp,
 - 2) IR BIAS control, and
 - 3) Time-delay control.

D-3.1.2 Test Voltage Power Supply — See power supply manual for the specific power supply used.

D-3.1.3 Indicator Power Supply — 'ON/OFF' switch, pilot light, fuse.

D-3.2 Adjustments — The following adjustments may be necessary for the test.

D-3.2.1 Momentary Breakdown Counter — 'COUNT BIAS' control.

D-3.2.2 Low IR Detector

- a) 'IR BIAS' control, and
- b) Time-delay control.

D-3.2.3 Test Voltage Power Supply — Test voltage control.

D-3.3 Adjustment Procedure — The adjustment procedures specified in D-3.3.1 and D-3.3.2 shall be adopted prior to each test.

D-3.3.1 Momentary Breakdown Counters

- a) Turn on indicator power supply: allow 3-minute warm up time.
- b) Install test capacitor current-limiting resistor R (calculated by the formula shown in D-1.1).
- c) Apply positive-going pulses having parameters as specified in D-2.1 across resistor R .
- d) Adjust the 'COUNT BIAS' counter responds to every pulse ± 3 percent:
 - 1) There is a time delay of a few seconds in the adjustment of the bias. A minimum of 5 seconds should be allowed between adjustments.
 - 2) Extreme counter clockwise rotation of this control will cause the circuit to oscillate and the counter will indicate between two numbers. To stop this oscillation, rotate the control clockwise until the counter releases.
- e) After the counters have been adjusted to respond to each pulse as specified in (c), apply pulses which are 80 percent ± 3 percent of the amplitude of the pulses specified in (c).
- f) Adjust the 'COUNT BIAS' control so that none of the counters respond to the pulse specified in (e).
- g) Recheck (c) to (f).

D-3.3.2 Low IR Detectors

- a) Apply the calculated low IR detection voltage across the resistor (R) of D-3.3.1(b). Low IR detection voltage is calculated by use of the following formula :

$$V = \frac{R}{R + R_{Min} E}$$

where

V =low IR detection voltage,

E =test voltage,

R =current-limiting resistance in ohms = $\frac{0.025}{C_{farad}}$, and

R_{Min} =The minimum allowable test temperature insulation resistance as applicable.

- b) Adjust the 'IR BIAS' control until one element of the 'IR' lamp indicates:
 - 1) Remove the voltage specified in (a) from each detector as soon as possible after adjustment.
 - 2) If the adjustment of a detector takes longer than 2 minutes, the time-delay circuit may lock the 'IR' lamp on after removal of the voltage. To reset this circuit, turn off the indicator power supply for at least 1 minute; set-up may be continued after 1 minute warm up.
 - 3) Time-delay circuits:
 - i) The time-delay control (*see D-3.1.1*) adjusts the low IR detection period. The 'IR' lamp shall be off prior to adjustment of this control.
 - ii) Apply voltage of (a) under low IR detectors to each detector.
 - iii) Record elapsed time from application of voltage to second 'IR' lamp element indication for each detector.
 - iv) Turn off indicator power supply and allow 5 minutes for resetting of low IR circuits.
 - v) Adjust time-delay control to 90 percent of specified time; clockwise to increase the time and counter clockwise to decrease the time.
 - vi) Turn on indicator power supply and recheck to ensure that the operating time does not exceed specified time.

D-3. Test Procedure

- a) Install test capacitors.
- b) Turn on indicator and test voltage power supplies.
- c) Allow 5-minute warm up time.
- d) Set test voltage to value specified.
- e) Turn electromechanical counters to zero by pressing reset button.

D-4. CALIBRATION INSTRUCTIONS

D-4.1 Equipment

- a) Counter pulse standard, and
- b) Microvoltmeter standard.

D-4.2 Calibration

- a) Observe operating instructions (*see D-3.1 and D-3.2*).
- b) Momentary breakdown counters:
 - 1) Turn on indicator power supply; allow 30-minute warmup time.
 - 2) Install 100 k Ω , 1W consuming resistor into test clips.
 - 3) Apply positive-going pulses of $5V \pm 2$ percent magnitude $3\text{ ms} \pm 10$ percent in width and at a repetition rate of $15\text{ pps} \pm 10$ percent cycle line tolerance across the 100 k Ω resistor.
 - 4) Adjust the 'COUNT BIAS' control until the counter responds to every pulse ± 3 percent:
See D-3.3.1(d).
 - 5) After the counters have been adjusted to respond to each pulse as specified in (3), apply pulses which are $4V \pm 2$ percent in magnitude and with the pulse width and repetition rate of (3).
 - 6) Adjust the 'COUNT BIAS' control so that none of the counters respond to the pulses of (5).
 - 7) Recheck (3) through (6).
- c) Low IR detectors:
 - 1) Apply $0.5\text{Vdc} \pm 1$ percent across the 100 k Ω resistor in (b)(2).
 - 2) Adjust the 'IR BIAS' control until one element of the 'IR' lamp indicates.
 - 3) *See D-3.3.2 (b) (1) and (2).*
- d) Time-delay circuits.
 - 1) *See D-3.3.2(b)(2) of operating instructions.*
 - 2) Apply voltage of D-4.2(c)(1) to each detector.
 - 3) Record elapsed time from application of voltage to second 'IR' lamp element indication for each detector.
 - 4) Turn off indicator power supply and allow 5 minutes for resetting of low IR circuits.
 - 5) Adjust time-delay control to 1.8 minutes; clockwise to increase the time counter clockwise to decrease the time.
 - 6) Turn on indicator power supply and re-check (3) through (5) to ensure operating time does not exceed 2 minutes.

APPENDIX E

(Clause 8.4.8)

SHOCK TEST

E-1. OBJECT

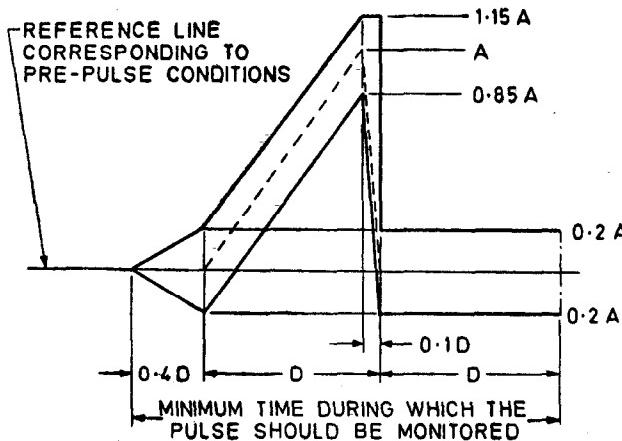
E-1.1 The object of this test is to determine the structural integrity and performance of capacitors when they are subjected to non-repetitive mechanical shocks.

E-2. TEST EQUIPMENT

E-2.1 When the shock test machine and the associated fixtures are loaded with the capacitor, the applied shocks shall, at the monitoring point, have any of the characteristics specified in C-2.2.

E-2.2 The shock test machine shall be capable of generating a pulse approximating to one of the following nominal acceleration versus time curves:

- a) Final peak saw tooth curve which is an asymmetrical triangle with a short fall time as shown by the dotted line in Fig. 15.



..... nominal pulse

— tolerance boundaries

D = duration of nominal pulse

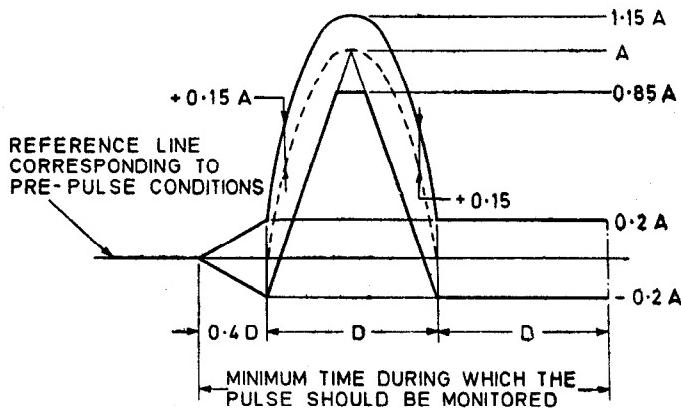
A = peak acceleration of nominal pulse

The reference line shall not differ more than 0.05A or 9.80 (± 0.98) m/s² or (10 ± 1 g), whichever is the greater, from zero acceleration.

FIG. 15 FINAL-PEAK SAW-TOOTH PULSE

- b) Half-sine curve which is one half cycle of a sine wave as shown by the dotted line in Fig. 16.
- c) Trapezoidal curve with short rise and fall times as shown by the dotted line in Fig. 17.

E-2.3 The true value of the actual shock pulse shall be within the tolerances shown by the solid lines in Fig. 15, 16 and 17.



..... nominal pulse

— tolerance boundaries

D = duration of nominal pulse

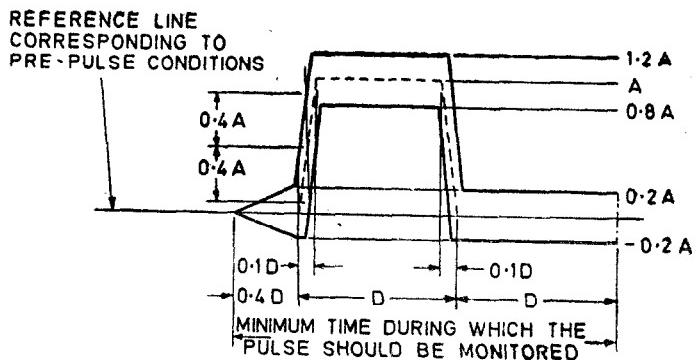
A = peak acceleration of nominal pulse

The reference line shall not differ more than $0.05A$ or $9.80 (\pm 0.98)$ m/s² or $(10 \pm 1 g)$, whichever is the greater, from zero acceleration.

FIG. 16 HALF-SINE PULSE

E-2.4 For all pulse shapes, the actual velocity change should be within ± 10 percent of the value corresponding to the nominal pulse. To determine the velocity change, the actual pulse should be integrated from 0. D before the pulse to $0.1 D$ beyond the pulse, where D is the duration of the nominal pulse (see Fig. 15, 16 and 17).

E-2.5 The positive or negative peak acceleration at the monitoring point perpendicular to the intended shock direction, shall not exceed at any time 30 percent of the value of peak acceleration of nominal pulse in the intended direction, when determined with a measuring system conforming to E-2.6 to E-2.8.



..... nominal pulse

— tolerance boundaries

D = duration of nominal pulse

A = peak acceleration of nominal pulse

The reference line shall not differ more than $0.05A$ or $9.8 (\pm 0.98)$ m/s² or $(10 \pm 1 g)$, whichever is the greater, from zero acceleration.

FIG. 17 TRAPEZOIDAL PULSE

E-2.6 The shock pulse shall be measured by an accelerometer placed the monitoring point. This point shall be the capacitor fixing point nearest to the centre of the table surface unless there is a fixing point having a more rigid connection to the table, in which case, the latter point shall be chosen.

E-2.7 The accuracy of the measuring system shall be such that it can determine the true value of acceleration within the given tolerance.

E-2.8 The frequency response of the overall measuring system, including the accelerometer, shall be within the limits shown in Fig. 18.

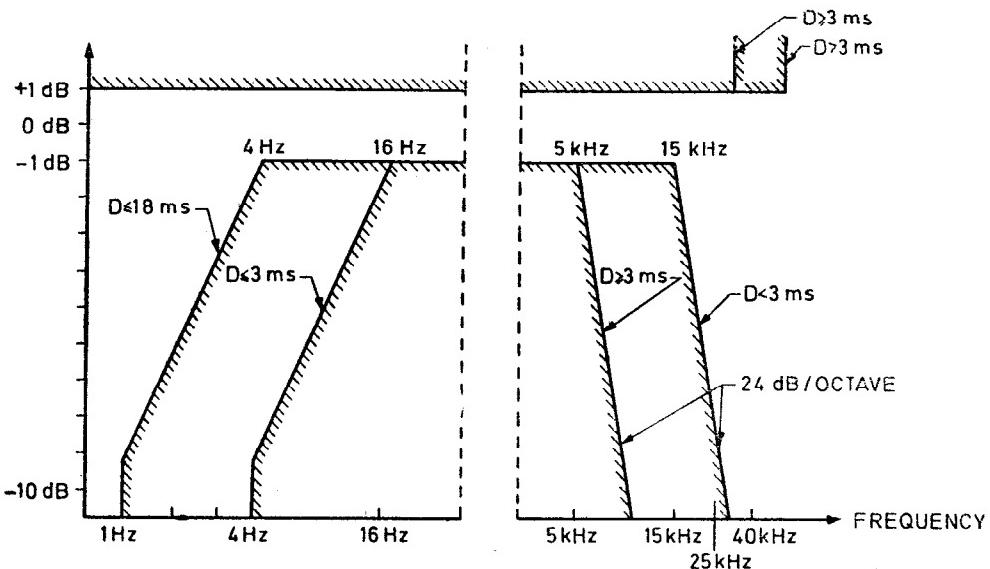
NOTE — When it is necessary to employ filters to reduce the effect of any high frequency resonance inherent in the accelerometer, it may be necessary to examine the amplitude and phase characteristics of the measuring system in order to avoid distortion of reproduced waveform.

E-3. TEST PROCEDURE

E-3.1 Mounting of Capacitors

E-3.1.1 The capacitor shall be secured to the shock test machine either directly or by means of a fixture as specified in E-3.1.2 to E-3.1.7.

E-3.1.2 Mounting fixtures shall be such as to subject the capacitors to shocks in each plane and sense.



Duration of Pulse ms	Low-Frequency Cut-Off Hz		High-Frequency Cut-Off kHz	Frequency Beyond Which the Response may Rise Above + 1 dB (kHz)
	- 1 dB	- 10 dB		
<3	16	4	15	40
3	16	4	5	25
$3 < D < 18$	4	1	5	25

FIG. 18 FREQUENCY CHARACTERISTICS OF THE MEASURING SYSTEM

E-3.1.3 Capacitor having a unique method of mounting shall be so mounted.

E-3.1.4 The mounting of capacitors not provided with unique means of mounting shall be such that the test conditions applied should dynamically load the body or terminations. Either the body and the leads or the leads only may be clamped as specified by the relevant capacitor specification.

E-3.1.5 Capacitors with axial terminations weighing less than 15 g shall be secured to rigid pillars leaving 5 to 8 mm between the point of emergence of the leads and the pillars. Similar capacitors weighing 15 g and more shall be clamped so as to avoid any stress on the leads.

E-3.1.6 Capacitors with radial terminations and capacitors having unusual mass distribution shall be mounted as specified in the relevant capacitor specifications.

E-3.1.7 External connections made to the capacitor for power supply and measurements shall add a minimum of mass and place a minimum restraint on the capacitor.

E-3.1.8 The relevant capacitor specification shall state whether the gravitational force is important. In case it is important, the capacitor shall be so mounted that the gravitational force acts in the same directions as it would in service use. Where the effect of gravitational force is not important, the capacitor may be mounted in any plane or sense.

E-3.2 Testing

E-3.2.1 A shock severity for a selected pulse shape (*see E-2.2*) shall be given by the combination of the peak acceleration and the duration of the nominal pulse. The relevant capacitor specification shall choose the appropriate severity from those listed in Table 4.

TABLE 4 SHOCK SEVERITIES

SL NO.	PEAK ACCELERATION		DURATION OF THE PULSE		VELOCITY CHANGE		
	(1)	(2) m/s ²	(3) g	(4) m/s	Final Peak Saw Tooth	Half-Sine	Trapezoidal
1.	294	30	18	2.65	3.37	4.77	
2.	—	30	11	1.62	2.07		
3.	490	50	11	2.69	3.43	4.86	
4.	—	75	6	2.19	2.80		
5.	981	100	6	2.94	3.74	5.30	
6.	4 900	500	1	—	3.12		
7.	—	1 000	0.5	—	3.11		
8.	14 700	1 500	0.5	—	4.68		
9.	29 400	3 000	0.2	—	3.74		

E-3.2.2 The half-sine pulse shape shall be the preferred pulse shape unless otherwise specified in the relevant capacitor specification.

E-3.2.3 The capacitors mounted as described in E-3.1 and electrically loaded if so required by the relevant capacitor specification shall be subjected to three successive shocks of appropriate severity in both the senses in each of the three mutually perpendicular planes so chosen that the faults are most likely to be revealed (that is, a total of 18 shocks).

E-4. INFORMATION TO BE GIVEN IN THE RELEVANT CAPACITOR SPECIFICATION

E-4.1 The following information shall be given in the capacitor specification:

- a) Preconditioning, if any;
- b) Initial measurements;
- c) The appropriate shock severity;
- d) The pulse shape, of other than half-sine;
- e) Whether gravitational force is important (*see E-3.1.8*);
- f) Any special mounting requirements (*see 3.1*);
- g) The details of electrical loading (*see 3.2.3*);
- h) Intermediate measurements and time intervals;
- j) Final measurements;
- k) Acceptable performance limits; and
- m) Any deviation from the normal test procedure.

A P P E N D I X F *(Clause 8.4.9)*

ACCELERATION TEST

F-1. OBJECT

F-1.1 The object of this test is to determine the structural suitability and satisfactory performance of capacitors during and after subject to a steady state acceleration.

F-2. TEST EQUIPMENT

F-2.1 The specified acceleration shall be applied by means of a suitable centrifuge. If the capacitors are sensitive to gyroscopic couples, the relevant capacitor specification shall specify the required acceleration conditions that should be realised using a machine capable of imparting linear acceleration to the capacitors.

F-3. TEST PROCEDURE

F-3.1 Mounting of Capacitors

F-3.1.1 The capacitors shall be secured to the centrifuges either directly or by means of a fixture as specified in F-3.1.2 to F-3.1.7.

F-3.1.2 Mounting fixtures shall be such as to subject the capacitors to acceleration in each plane and sense as specified.

F-3.1.3 Capacitors having a unique method of mounting shall be so mounted that for severities 10 000 to 20 000 g suitable protection is provided for capacitor terminations.

F-3.1.4 The mounting of capacitors not provided with unique means of mounting shall be such that the test conditions applied should dynamically load the body and/or terminations. Either the body and the termination or the terminations only may be clamped as specified by the relevant capacitor specification.

F-3.1.5 Capacitors with axial terminations weighing less than 15 g shall be secured to rigid pillars leaving 5 to 8 mm between the point of emergence of the terminations and pillars. Similar capacitors weighing 15 g and more shall be clamped so as to avoid any stress on the terminations.

F-3.1.6 Capacitors with radial terminations and capacitors having unusual mass distribution shall be mounted as specified in the relevant capacitor specification.

F-3.1.7 External connections made to the capacitors for power supply and measurements shall add minimum of mass and place minimum of restraint on the capacitor.

F-3.2 Testing

F-3.2.1 The relevant capacitor specification shall indicate the applicable acceleration severity chosen from the values given as follows:

<i>Sl No.</i>	<i>Acceleration</i>
1	17
2	50
3	100
4	Under consideration
5	10 000
6	20 000

F-3.2.2 The specified acceleration-severity shall be applied to the capacitors in both senses in each of the three mutually perpendicular planes, unless otherwise specified by the relevant capacitor specification.

F-3.2.3 For severities at Sl No. 1, 2, 3 and 4 in F-3.2.1 the duration of the acceleration in each sense shall be 5 minutes, so that the capacitors are accelerated for total period of 30 minutes.

F-3.2.4 For severities at Sl No. 5 and 6 in F-3.2.1 the duration of the acceleration in each sense shall be one minute so that the capacitors are accelerated for a total period of 6 minutes. For these two severities, the rise and decay times of the acceleration shall each be not less than 20 seconds.

F-3.2.5 The acceleration measured at any point on the capacitor shall be within 15 percent of the specified value unless otherwise specified.

F-3.2.6 During the test, capacitors shall be loaded and/or operated and measured, if so specified by the relevant capacitor specification.

F-3.3 Recovery —The capacitors shall then be allowed to remain under recovery conditions for a period of 1 to 2 hours or as specified by the relevant capacitor specification.

F-4. INFORMATION TO BE GIVEN IN THE RELEVANT CAPACITOR SPECIFICATION

F-4.1 The following information shall be included in the capacitor specification:

- a) Preconditioning, if any;
- b) Initial measurements;
- c) Detail of test equipment if other than a centrifuge (*see F-2.1*);
- d) Any special mounting requirements (*see F-3.1.2*);
- e) The applicable severity (*see F-3.2.1*);

- f) Details of electrical loading (see F-3.2.6);
- g) Intermediate measurements and time intervals;
- h) Period of recovery, if other than 1 to 2 hours;
- j) Final measurements;
- k) Acceptable performance limits; and
- m) Any deviation from the normal test procedure.

A P P E N D I X G

(Clause A-4(e))

PULSE TESTING OF CAPACITORS

G-1. INTRODUCTION

G-1.1 The normal test methods are suitable for capacitors operating in the electric circuits in which the applied voltage is predominantly dc. There is now an increasing number of applications in which the applied voltage is in the form of pulse with or without a reversal of polarity. These pulses may be continuous, intermittent, or random in occurrence.

G-1.2 This standard sets down the factors affecting pulse ratings and the way in which these ratings may be checked by appropriate endurance tests. The parameters of a pulse are defined. Different combinations of these parameters can give rise to different mechanisms of failure as follows:

Type

Electrolytic	Surge voltage exceeded	Surge voltage
	Reverse voltages exceeded	Reverse voltage
	Overheating ($I^2 R$)	Pulse or ac
Metallised types	Peak current	Charge/Discharge (Intermittent)
	$\frac{dv}{dt}$	pulse
	Overheating ($I^2 R$)	Pulse or ac
	Ionisation	ac
All other	$\frac{dv}{dt}$	Pulse
	Overheating ($I^2 R$)	Pulse or ac
	Excess peak voltage	Surge
	Ionisation	ac

G-2. TYPICAL CAPACITOR PULSE CONDITIONS

G-2.1 The figures listed below for typical applications show that test specifications requiring 100 000 or 1 million pulses correspond to lives of only 5 to 50 seconds.

G-2.2 It will not be possible to produce one circuit which will reproduce all of the required conditions. It is likely, however, that circuits can be produced which will reproduce various groups of conditions. It does not appear possible at the present time to accelerate the conditions to correspond, for example, with a 5 year life.

G-2.2.1 Examples for TV Applications

Si-Correction : Typical peak voltages: 25, 50, 180 V

Typical peak currents : 5 to 15 A

$$\frac{dv}{dt} \text{ about } 5 \text{ V/}\mu\text{s}$$

frequency: 15 to 20 kHz

VA_r up to 250 VA

Line tuning: Typical peak voltages : up to 1 500 V

Typical peak currents 5 A

$$\frac{dv}{dt} = 180 \text{ } V/\mu\text{s}$$

Multiplier capacitors: Typical peak voltages 10 kV dc with ripple

Typical peak current 0·1 A

$\frac{dv}{dt}$ up to 1 000 V/ μ s

G-2.2.2 Examples for Power Electronics

Typical peak voltage: 60 to 100 V

Typical peak currents: 40 to 100 A

$\frac{dv}{dt}$ from 1 to 20 V/ μ s

frequencies 50 Hz to 20 kHz

VA_r up to 500 VA

G-2.2.3 Examples for dc-dc-converters

Typical peak voltage	30 V
Typical peak current	6 A
$\frac{dv}{dt}$	600 V/ μ s

G-2.2.4 Examples for Lasers and Pulse Light Sources

Typical peak voltages	1 to 3 kV
Typical peak currents	1 000 A
$\frac{dv}{dt}$	about 500 V/ μ s
Frequencies	1 to 5 kHz

G-3. EFFECT OF INDUCTANCE ON PULSE TESTING

G-3.1 Proposed pulse test methods are likely to consist of test circuits involving repetitive charge and discharge of capacitors in resistive circuits. This will result in conventional exponential current and voltage characteristics. In many applications, however, inductive effects are of considerable importance and have a major influence on the suitability of the capacitor for the application. These are particularly important at high values of $\frac{dv}{dt}$. If the conditions for critical damping exist ($R^2 = 4 \frac{L}{C}$) the effect is a minor modification of the shape of the charge or discharge curve which will have little effect on the severity of the test. If, however $R^2 < 4 \frac{L}{C}$ there can be overshoot with or without damped oscillations. These can result in overstress and increased power dissipation.

Note — C is capacitance and L is inductance.



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